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Evaluating the Impact of Policies on Production Efficiency of Nigeria's Rice Economy

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Abstract

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Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

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Public Policy and Public Administration

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Abstract

Nigeria, like all other rice consuming nations, has experienced a surge in domestic demand for rice since 1970. However, local rice production has not been sufficient to meet local demand, leading to this demand continually being filled by imports. The Federal Government of Nigeria has initiated subsidies programs intended to improve Nigerian rice farmers' technical and cost efficiency levels. This quantitative study evaluated the impact of these policies on the technical and cost efficiency levels of paddy rice farm households in Nigeria. Farrell's (1957) efficiency theory and production theory served as the theoretical frameworks. Data were collected from a cross-section of 300 paddy rice farmers drawn from 3 states in Nigeria. The study used 2 estimation techniques: parametric technique (SF) and the non-parametric technique (DEA). The results showed that paddy rice production in Nigeria was still profitable but low and the estimated average technical and cost efficiency levels from the DEA approach were 0.721 and 0.295, respectively. Evidence suggests that the formulation and implementation of subsidy programs on farm inputs were relevant in the variations of technical and cost efficiency levels across the rice farm households. The study findings support the continuity of the subsidy policies to encourage increased rice production; they also suggest that governments should address the issues of post-harvest losses, degrading irrigation facilities, and ineffective rural development policies. The positive social change implications of this research include providing information to inform government policy changes designed to more effectively address rice importation and pricing, positively impacting the standard of living for rural farmers and communities in Nigeria.

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Dedication

To my family: I owe so much for your understanding and moral support during the period of study and writing this dissertation. I also dedicate this manuscript to my late father, Mr. Lawrence N. Rapu.

Acknowledgments

Many people contributed to this project in various ways, and at different stages of the design and execution, therefore I wish to thank them profoundly. I am particularly indebted to the Chairperson and other members of my committee, Dr. Lori Demeter, Dr. Augusto V. Ferreros, Dr. Kathleen Schulin, and Dr. Basil Considine who assisted me in developing and finalizing this dissertation. I also wish to thank my former colleagues at the Central Bank of Nigeria, Abuja – Dr. Moses Nkang, Kamal Ajala and Izuchukwu Okafor who assisted me greatly through many discussions and ways to ensure that this dissertation was produced.

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Chapter 1: Introduction to the Study

Background

Rice production and consumption are of global importance, providing more than 20.0% of caloric needs of millions of people on daily basis (Yang & Zhang, 2010). In terms of annual world production and consumption of major cereals, rice is the third most-produced and consumed cereal after maize and wheat (Food and Agriculture Organization [FAO], 2012). Nigeria, like all other rice consuming nations, has experienced a surge in domestic demand for rice since 1970 (Odusina, 2008). As a result, rice has become a strategic staple dietary household item in Nigeria, especially among lower-middle and low-income groups (Kanu & Ugwu, 2012). The annual consumption of milled rice in Nigeria increased from 0.4 million metric tons in 1960 to approximately 5.2 million metric tons in 2013, reflecting an annual average growth rate of 7.2% (International Rice Research Institute, 2013). In Nigeria's household consumption, rice is the fifth-most common food after tubers, vegetables, beans, sorghum, and other cereals, representing about 5.8% of households' spending (Johnson, Hiroyuki, & Gyimah-Brempong, 2013).

The per capita annual consumption in Nigeria has also accelerated from 1.6 kg in 1960 to approximately 31.6 kg per annum in 2013. This increase is driven by growth in population, urbanization, increases in per capita income, and changes in preferences for rice meals (Omojola, Effiong & Pepple, 2006). For instance, average annual growth rate of population has fluctuated between 2.2% in 1960s to 2.9% in 2013 (World Bank, 2014). Population growth generally induces a rapid increase in food consumption, especially rice.

Similarly, since 1970 Nigeria has consistently experienced increases in per capita income due to inflows of petro-dollars, which have pushed up food per capita consumption in general and rice per capita consumption in particular. These increases in per capita income were also responsible for some of the changes that have occurred over in Nigerian consumer taste and preferences for rice (Abayomi, Bamidele & Esther, 2010).

The increase in demand for rice in Nigeria since 1970 has not been accompanied by a sizeable increase in local rice production, resulting in the widening of the local supply-demand deficit (Damisa, Oyinbo, & Rekwot, 2013). As a result, the annual increase in local rice production is lagging behind the annual increase in local demand. This slow growth in local rice production has widened the gap between local supply and demand for rice in Nigeria, meaning that self-sufficiency ratio in terms of local production is continuously declining. To meet this annual deficit, Nigeria has expended substantial foreign exchange earnings to import rice (Amusan & Ayanwale, 2012).

The inability of the rice subsector to produce enough rice for local consumption is attributed to the neglect of the subsector over the years by governments. This is traced mainly to the shift of emphasis by government annual expenditure associated with the discovery of crude petroleum in 1970s (Nchuchuwe, 2012). As earnings from crude petroleum became the most important contributor to government revenue, emphasis of government expenditure shifted at the detriment of the agricultural sector (Abbass, 2012). An important outcome of petro-dollar inflows is the downgrading of agricultural pursuits, which made agricultural activities less profitable and less attractive to the youth population. This was also another major contributor to low rice production outputs compared to demand.

As a result of these developments, the Federal Government of Nigeria initiated policies between 2011 and 2013 to intervene in the agricultural sector in general and the rice subsector in particular (Adesina, 2012). By and large, public policy reflects actions of government to tackle future occurrence of a societal problem (Chamon & Kaplan, 2013). Therefore, rice subsector policies were formulated in order to reduce the dependence on international rice market to meet local rice demand. The policy initiatives put in place were intended to address the local rice supply-demand gap through improvements in production efficiency of Nigeria's rice economy.

The production efficiency of a producer consists of the ratio of observed output, cost or profit to potential output, minimum cost, or maximum profit that a producer can attain (Ferdushi, Abdulbasah-Kamil, Mustafa, & Baten, 2013). Therefore, rice subsector policies are targeted at removing constraints to increased productive efficiency facing the local rice industry. These constraints include: inadequacy and high price of inputs such as fertilizer, rice seeds, herbicides, insecticides, poor access to farm credits, land, extension services, poor rural infrastructure and irrigation facilities, market failures in local paddy rice market and high rice milling costs (Nwinya, Obienusi & Onouha, 2014).

At the time of this study, the Federal Government of Nigeria has initiated several strategic policies and programs to address low production efficiency in Nigeria's rice subsector. These policies are designed to address factors that are believed to be inhibiting higher productivity and the ability of the local rice subsector to meet local demand. These policies, programs and projects include: the national fertilizer policy, national seed policy, land use policy, national extension service policy, agricultural credit guarantee scheme fund (ACGSF), commercial agriculture credit scheme, national irrigation policy, government guaranteed minimum producer's price, rice trade policies and rural development programs. The Federal Government of Nigeria also simultaneously created several agricultural institutions, agencies, research institutes and universities to implement these policies and programs. The institutions include: Agricultural Development Projects (ADPs), River Basin Development Authorities (RBDA), Bank for Agriculture and Rural Development (BOI) and National Cereal Research Institute (NCRI) and other research institutes. The federal, state and local governments have also encouraged rice farmers to form cooperative societies so as to enhance their credit worthiness and to enable them benefit from the these policies, programs and projects.

In general, the federal, state and local governments are using the platform of the Presidential Initiative on Rice to augment these policies and programs. The strategic themes of the Presidential Initiative on Rice include: the introduction of a 100% duty levy on imported polished rice, distribution of R-boxes to rice farmers, and introduction of 50% duty rebate on imported brown rice (Federal Ministry of Agriculture and Rural Development [FMARD], 2011). R-Box is a conservation tillage rice production technology pack that was researched and developed by the CANDEL Company in 2003 to aid food security of rural dwellers. R-box contains a complete package of rice and other inputs needed to plant 1⁄4 hectare (International Institute of Tropical Agriculture [IITA], 2004). Brümmer et al. (2004) identified positive relationships between improvements in productive efficiency of producers, increase in output and economic growth. These relationships are pertinent since increase in local rice output is expected to create a substantial reduction in rice import, thereby conserving foreign exchange for other sectors, while also generating additional employment and income for rural households.

Nigeria's rice economy comprises actors such as local paddy rice farmers, local rice millers and the local network of distributors. The paddy rice farmers are the primary actors in the rice value chain since the paddy rice production is the platform for other actors and therefore, were the main focus of this study. To date, empirical studies on rice farm production efficiency in the literature, have employed farm production and cost or profit functions to estimate the efficiencies associated with paddy rice producers and to evaluate the impact of policies on the estimated production and economic efficiency scores (Chiona, Kalinda & Tembo, 2014; DeSilva, 2011; Galluzzo, 2013; Hoang & Yabe, 2012).

These studies have also associated the concept of efficiency of rice farms with technical, allocative and economic efficiency measures. Some researchers have employed all of the three dimensions of efficiency, while others have used one or a combination of the concepts to evaluate the impact of policies on production and economic efficiency of paddy rice farms. In doing so, these empirical studies applied the theoretical definitions of production, cost and profit functions, assuming that the primary objective of farm households is profit-maximization (Akudugu, Guo & Dadzie, 2012). Thus, profit maximization was assumed in this study as the sole production objective of Nigeria's paddy rice farmers, in alignment with Bäckman, Islam and Sumelius (2011). Basically, the study was conducted in three states in Nigeria namely: Kaduna, Niger and Nassarawa States.

The investigations were conducted in two steps. In the first step, the respective efficiency scores for individual paddy rice farmers for the technical, allocative and economic efficiency (cost efficiency) measures were estimated. In the second step, the scores of the technical and economic efficiency scores obtained in the first step were used as dependent variables and regression analysis was performed against independent policy initiatives. However, the joint effect of the policy variables was controlled with farm-specific socio-economic characteristics.

In the literature, two common approaches to efficiency estimations are parametric and nonparametric approaches. The main parametric methods are the ordinary least square (OLS) and the stochastic frontier (SF) models, which are embedded in classical regression estimation procedures (Aigner, Lovell & Schmidt, 1977). The widely applied nonparametric approach is data envelopment analysis (DEA) introduced by Charnes, Cooper and Rhodes (1978). This approach is not, however, embedded in a regression framework; instead, it uses linear programming estimation technique.

I employed these two approaches in this study to independently estimate the technical and economic efficiency levels of paddy rice farmers in Nigeria. The DEA-generated technical and economic efficiency levels were only employed to evaluate the impact of policies on the overall technical and cost efficiencies of the paddy rice farm households. This procedure was justified because the results showed that the DEA models generated technical and economic efficiency scores were more conservative and statistically reliable than the SF technical and economic efficiency scores (Gabdo, Abdlatif, Mohammed & Shamsudin, 2014).Moreover, the application of the two approaches was relevant because of the need to generate robust and comparative results that could serve as useful inputs to policy formulation and implementation.

Overall, the data for the estimation of the respective efficiency measures and the impact of policies on the technical and economic efficiency scores were obtained from a cross-section survey of paddy rice farm households in the selected three states. The respondents were selected using multiple probability sampling techniques: stratified, cluster, and simple random sampling approaches, as recommended by Frankfort-Nachmias and Nachmias (2008). A total of 300 paddy rice farmers were sampled for the survey, representing about 100 participants from each of the three states covered during the survey. The equal number of participants from each state was justified because there was no prior knowledge of the exact population of rice farming households in each of the states. Generally, none of the states in which the survey was conducted could provide an appropriate list of the population of the paddy rice producers in their states.

I employed a multistep analysis in the study due to the differences in rice production technology across the three sampled states. First, the *consolidated frontier* that covered the combined data from all the states' samples was constructed for technical and economic efficiency measures, respectively. This frontier reflected a combination of all the data collected from respondents irrespective of the states samples. In the next step, the *state frontiers* were constructed for respective states' technical and economic efficiency scores. The second frontier estimated the respective technical and economic efficiency measures of individual farmers relative to the technologies peculiar to the states. Therefore, it provided the platforms that identified the technology gap across the three sampled states. While the former frontier showed the technical and economic efficiency levels in respect of the unrestricted rice production technology, the latter represented the restricted production technology for each of the sampled states. The data were analysed using an Excel spreadsheet, PIM-DEA Version 3.2, and STATA Version 14.1 software.

The remainder of this chapter contains the problem statement and purpose of the study. This is followed by the research questions and hypotheses that were answered by this study. Afterwards, the nature of study is discussed which identified the research methods and the scope of study. Next, the theoretical foundation of the study is explored, thus anchoring the theoretical foundation for this study. Following this are the brief definitions of concepts of public policy and efficiency measure, and data and analytical framework employed in the study. The chapter also highlights the assumptions and limitations, and it concludes with the significance of study to policy, knowledge and social change.

Problem Statement

Nigeria is the largest producer and consumer of rice in West Africa and in sub-Saharan Africa (SSA), but its local rice supply-demand deficit has persistently expanded. Although local rice production has increased since 1990s but the increase has not been sizeable enough to satisfy local rice demand (Johnson et al., 2013). This has resulted in a large domestic supply-demand gap, leading to massive importation of rice products (Aminu, Obi-Egbedi, Okoruwa, & Yusuf, 2012).

Table 1

Selected Indicators for Nigeria's Rice Economy

Indicators	Average 1960-1979	Average 1980-1999	Average 2000-2010	Average 2011-2013
Milled Rice Production (million/metric tons)	0.3	1.3	2.2	2.9
Growth rate of production (%)	2.9	11.3	3.6	4.0
Milled Rice Consumption (million/metric tons)	0.4	1.9	3.9	5.2
Growth rate of consumption (%)	8.0	8.4	5.0	3.5
Self-sufficiency ratio (%)	75.0	68.4	56.4	53.8

Notes. Data sourced from International Rice Research Institute [IRRI] Database: Retrieved from http://ricestat.irri.org:8080/wrs2/entrypoint.htm and Food and Agricultural Policy Research Institute [FAPRI] Database: Retrieved from http://www.fapri.iastate.edu/outlook2007/

At the time of this study, the significant costs of importing rice in Nigeria represent a substantial drain of scarce foreign exchange resources. For example, locally milled rice production increased from an average of 0.3 million metric tons per annum in 1960 to an average of 2.8 million metric tons in 2013, representing an average annual growth rate of

6.1%. However, local demand for milled rice products has increased much faster from an average of 0.4 million metric tons per annum in 1960 to an average of 5.2 million metric tons in 2013, representing an average annual growth rate of 7.2% (see Table 1).

The imbalance between Nigerian rice cultivation and consumption is a significant long-term concern. According to the outlook from the Food and Agricultural Policy Research Institute [FAPRI] Database, (2007), the local demand for rice and allied products is projected to rise to 7.2 million metric tons by 2018, while local production of milled rice is projected to reach only 3.7 million metric tons. By implication, local supply gap of 3.5 million metric tons must be filled by importation of rice in order to avoid hunger and disease by 2018. Thus, Nigeria will need to allocate more foreign exchange earnings for importation of rice in order to meet local supply gap in the future (Global Agricultural Information Network [GAIN], 2012).

Estimates however, showed that locally milled rice output as a ratio of total domestic demand defined as self-sufficiency ratio was 75.0% in 1960s and 1970s. This dropped to 68.4% in 1980s and 1990s and has also trimmed down to 53.8% by 2013. However, this is projected to drop further to about 51.4% by 2018. The problem of massive importation of rice can be better appreciated by the available statistics that showed Nigeria as the second largest global importer of rice after China in 2013 (United States Department of Agriculture [USDA], 2012).

Available data on formal rice import also revealed an average increase of 12.8%, 8.6% and 3.5% per annum during the periods 1980-1999, 2000-2010 and 2012, respectively. The volume of formal rice import, nevertheless jumped to about 2.0 million metric tons, reflecting an annual average growth rate of 6.0% in 2013 (see Table 2).

Table 2

Selected Indicators for Nigeria's Rice Imports

Indicators	Average 1960s	Average 1970s	Average 1980-1999	Average 2000-2010	2012	2013
Volume of rice imports (million metric tons)	0.1	0.2	0.6	1.8	1.9	2.0
Growth of imports (%)	5.0	256.3	12.8	8.6	3.5	6.0
Value of rice imports (US$ million)	0.2	84.1	115.7	443.1	1,920.2	2,041.3
Food imports (US$ million)	65.8	749.9	1,223.8	2,756.8	11,433.3	12,153.6
Share of rice imports in food imports (%)	0.4	5.3	15.7	16.8	16.8	16.8

Notes. Data sourced from the International Rice Research Institute (IRRI) Database (http://ricestat.irri.org:8080/wrs2/entrypoint.htm), Food and Agricultural Policy Research Institute (FAPRI) Database (http://www.fapri.iastate.edu/outlook2007/e), and the Central Bank of Nigeria (CBN) 2012 Annual Report and Statement of Accounts (http://comtrade.un.org/db/dq).

Similarly, the value of rice import increased steadily from an average of US$0.2 million in 1960s to about an average of US$84.1 million per annum in 1970s. The value of rice imports, however, more than doubled to an average of US$442.3 million per annum between 2000 and 2010 and moved up rapidly to about US$1,920.2 million in 2012 and an estimated $2,041.3 million in 2013 (see Table 2). As a share of total value of food imports, rice imports expanded from an average of 0.4% per annum in 1960s to an average value of 5.3% per annum in 1970s and moved upward to 15.7% per annum between 1980 and 1999. Rice imports further increased in 2013 to a share of 16.8% of total food import. Their share of visible imports was also estimated at 6.6% in 2012 (Central Bank of Nigeria [CBN], 2012).

This persistent increase in the volume and value of rice imports into Nigeria has economic, socio-cultural, and political implications (Odusina, 2008). Rice imports by Nigeria come from diversified sources, but primarily from Asian countries such as Thailand, India, and Vietnam. However, in recent years, the United States, United Arab Emirates, Europe, and Brazil have also significantly increased their shares of rice exports to Nigeria (Cadoni & Angelucci, 2013).

The desire to stem increasing local rice supply deficit and reverse persistent rice importation has prompted Federal Government policy actions and interventions. These government actions and interventions were further motivated by available evidence that Nigeria is naturally endowed with viable ecologies that are suitable for massive cultivation of different rice varieties and should therefore not rely on importation of rice to feed her population (Adesina, 2012). Nigeria's potential land area for rice cultivation of between 4.6 and 4.9 million hectares, but fewer than 2.3 million hectares (47.0%) of this land are currently utilized for cultivation of the product (Adewumi & Rahji, 2008).

A number of broad economic and environmental constraints have also been identified that are militating against improving production and economic efficiency levels as well as higher output by paddy rice farm households in Nigeria. These are: low utilization of fertilizer and other farm chemicals, use of poor varieties of rice seeds, impact of market failures, failure of extension services, and lack of rural infrastructure (Nin-Pratt, Johnson, Magalhaes, Diao & Chamberlin, 2010). Other factors include: frequent floods, irregular patterns of rainfall, water shortage, and poor credit delivery to farmers. As a consequence, many small-scale paddy rice farmers are trapped at subsistence levels of rice production, discouraging taking actions to promote a higher productive and economic efficiency and the commercialization of rice production.

Purpose of the Study

The overall objective of this quantitative study was to evaluate the impact of policies on technical and economic efficiency measures of Nigerian paddy rice farmers for the 2014/2015 cropping season. I examined potential positive relationships between government policy actions/interventions and the technical and economic efficiency levels of paddy rice farmers in Nigeria, using 3 selected states out of the 36 federated states. The key policy issues of interest in this study were access to subsidized inputs (fertilizer, seeds, herbicides/insecticides and mechanization) and extension services. Primary data were therefore collected from approximately 300 selected paddy rice farmers in the states of Kaduna, Nassarawa, and Niger.

Thus, I examined the contributions of rice subsector policies to enhancing production and cost efficiency measures and output of paddy rice farmers across the selected states in Nigeria. Since the study covered a wider geographical base compared to other studies in the subsector that are basically localized, it is believed that the findings will add value to policy formulation and implementation. The use of multiple states in this study was a result of recognition of differences in resource endowments across states in the country. Specifically, the following objectives are identified. To:

- Estimate rice farms technical and economic efficiencies,

- Evaluate impact of policies on variations in observed farms' technical and economic efficiency scores; and
- Determine whether variations in specific socioeconomic characteristics have significant control on policy interventions.

Research Questions and Hypotheses

The research questions and their corresponding hypotheses are as follows:

Research Question 1 (Q1). Is technical efficiency of Nigerian paddy rice farmers influenced by rice subsector policies?

H_0: Government rice subsector policies have no influence on technical efficiency of paddy rice farmers in Nigeria.

H_A: Government rice subsector policies have influence on technical efficiency of paddy rice farmers in Nigeria.

Research Question 2 (Q2). Is economic efficiency (cost efficiency) of paddy rice farmers influenced by rice subsector policies?

H_0: Government rice subsector policies have no influence on economic efficiency of paddy rice farmers in Nigeria.

H_A: Government rice subsector policies have influence on economic efficiency of paddy rice farmers in Nigeria.

Nature of Study

In this quantitative study, I used a cross-section survey to obtain primary data to evaluate the impact of policies on technical and economic (cost) efficiency measures of paddy rice farms from three selected states in Nigeria. The survey design for this study covered three states using paddy rice farm households as participants. Thus, the data were collected employing a survey of paddy rice farms, which was conducted using an interview technique and a structured questionnaire.

The choice of the design was anchored on two reasons. First, the design enabled the researcher to make numerical inferences on the causal relationships between government rice subsector policies, and technical and cost efficiency of paddy rice farmers in Nigeria, using numerical data collected from the fieldwork in the three selected states. Moreover, the absence of reliable historical data on the activities of rice farmers in the sampled states informed the choice of a cross-section data instead of panel data. In consideration of states' contributions to national rice output, the selected three states were Kaduna, Nassarawa, and Niger.

To determine the national sample size, a sample size equation was employed as illustrated in equation 1 below.

$$n_0 = \frac{Z^2 pq}{e^2} \qquad (1)$$

In this equation, n_o is the sample size, Z^2 is abscissa of the normal curve representing the alpha level, e is the desired level of precision commonly called the margin of error, *p* is an estimated variation of the rice farming population, representing their exposure to government policies, and q is 1-*p* (Cochran, 1963). Thus, Equation 1 gave a state sample size of 100 and a combined sample size of 300 participants. The use of the sample size equation was germane because the exact population of rice farming households was unknown therefore this made it impossible to use the sample size table in this study.

Selection of participants for the survey employed multiple sampling techniques, which was intended at ensuring internal and external validity of the findings. The techniques included the various forms of probability sampling techniques such as: stratified, cluster and simple random sampling procedures. While stratified sampling technique was used for the selection of states and local governments, the cluster sampling was applied to select rice-producing wards/villages. Simple random sampling was used to select respondents from the clusters.

To ensure face and content validity, the structured questionnaire employed for the survey were first evaluated by two experts in the field of agricultural economics, who are staff of Research Department of the Central Bank of Nigeria. This was aimed at validating the survey instrument and ensuring that the questions were in tune with what they were intended to measure. In addition, prior to actual data collection, the survey instrument was first tested using a sample of 2 participants from Nassarawa State. The survey instrument was however revised as needed, based upon expert advice and then subsequently pilot test feedback.

Data analysis used parametric and nonparametric efficiency estimation approaches. The nonparametric tool was the data envelopment analysis (DEA). The DEA was introduced by Charnes, Cooper, and Rhodes (1978). The approach uses a linear programming technique to derive producers' efficiency levels. On the contrary, the parametric approach is motivated by a regression-based estimation method. The common parametric approach applied for estimating efficiency scores of producers in the literature is stochastic frontier (SF) model. Specifically, the estimation procedure frequently applied by researchers under the SF is maximum likelihood (ML) estimator (Balogun & Ogheneruemu, 2012; Belotti, Daidone, & Ilardi, 2012).

In recent years, efficiency estimations have also witnessed refinements. For example, in DEA approach, researchers have introduced regression frameworks by using a two-stage procedure rather than a single-stage procedure (Aragon, Daouia & Thomas-Aguan, 2005; Ceyhan & Hazneci, 2010; Fried, Lovell, Schmidt &Yaisawarng, 2002). In the case of SF model estimation, researchers have also applied single-stage and two-stage procedures to estimate efficiency levels of producers. The single-stage model in the DEA and SF approaches use input-output data as well as the contextual variables such as policies, environmental factors and socioeconomic factors all at once. These contextual variables are considered to have influences on efficiency levels of producers, and as such are capable of explaining the variations of efficiency scores, among producers. The two-stage model however applies input-output data to estimate first, the respective efficiency scores of producers. At the second stage, the respective efficiency scores for individual producers obtained from the first stage are regressed against all of the contextual variables and they are used to account for variations in efficiency scores across producers.

Notwithstanding the debates on the merits and demerits of these two approaches, the two comparative approaches - DEA and SF were employed simultaneously to evaluate the impact of policies on the respective technical and cost efficiency measures of Nigerian paddy rice farmers based on the data generated from the cross-section survey. These comparative estimation approaches used in the study generated strong comparative estimates that are believed to be useful for policies. Since the two approaches have their respective strengths and weaknesses, the researcher was therefore encouraged to explore these strengths. However, for each of these approaches, a two-stage estimation procedure was adopted.

Theoretical Foundations of the Study

This study leveraged on the popular theories of production and cost in microeconomics and efficiency measures as proposed by Farrell (1957). Accordingly, the concepts of production and cost efficiency are formally motivated by the theoretical definitions of production and cost functions. Empirical efficiency frontier production and cost functions specify the maximal output from given inputs or the minimum cost for given output and factor prices (Mendola, 2007). The concept of production efficiency treats producing units as independent decision-making units (DMUs) that are homogeneous by producing the same or similar goods or services (Farrell, 1957).

From theoretical perspective, the theory of production explains the transformation process of physical inputs (e.g., labor and capital) into outputs. The production technology represents the ability of the producer to transform inputs into output. In economics, the production transformation is expressed mathematically using a production function. Hence, the production function is defined as the mathematical expression, which indicates the maximum output that a producer can produce, given available physical inputs. In other words, it mirrors the level of technical efficiency in production process by showing the ratio of observed output to the maximum level of output that a producer can produce, using given inputs (Agom, Ohen, Itam, & Inyang, 2012).

Thus, in a more general form, if inputs and output are treated as two separate categories, then the technical functional relationship between the two categories can be expressed as *F(x, y)* = 0, where x is defined as *J* dimensional vector of nonnegative inputs used to produce *M* dimensional vector of nonnegative outputs (Kumbhakar, Wang, & Horncastle, 2015). In the single nonnegative rice output case, the generalized production function form can be expressed as:

$$y = f\left(x_1, x_2, \ldots\ldots x_j\right) \equiv f\left(x\right) \qquad (2)$$

By extension, the economic efficiency of farms can also be estimated using either the cost function or revenue and profit functions, if the factor prices and output prices are known.

For instance, the cost frontier is derived from the assumption of the behavioral objective of a producer, which is cost minimization. The cost minimization objective function assumes fixed market prices for the inputs used in the production process. Put simply, it assumes a perfect competition as such no producer in the market can influence input and output prices as everyone is a *price taker*. The cost structure of the producer in the short-run has a combination of fixed and variable costs. But in the long run, all costs are variable and the cost minimization occurs at a point where the slope of firm's isoquant line is equal to the ratio of input prices known as the isocost line. The isoquant line is therefore, defined as the technically feasible combinations of all inputs in the production process that produces the maximal output. The isocost line is also defined as the possible combinations of production inputs given the factor prices.

However, in the empirical literature, the expressions of production and cost frontiers for the purpose of estimating levels of producers' efficiency differ in the two selected approaches for this study that is, the DEA and SF estimation approaches. The DEA approach does not require an outright specification of the functional form of producers' reference technology. It simply requires the characterization of the production technology with the type of scale of operations and the production plan. This is generally referred to as the return-to-scale explaining the impact of changes in the level of inputs on the levels of output. The production plan refers to whether the producers seek to minimize inputs or maximize output that is input-oriented or output-oriented production plan.

On the contrary, the SF approach requires that the reference technologies of firms are expressly depicted in functional forms in terms of the production and cost functions. The most frequently applied functional forms of production technologies are: Cobb-Douglas and translog production and cost functions. In this study, the production and cost functions of the rice producers were specified as Cobb-Douglas production and translog cost functions. Thus, the neo-classical two-factor Cobb-Douglas production function in this study was denoted as:

$$Y_t = e^{at} L^b K^{(1-b)}, \text{ for } 0<b<1 \qquad (3)$$

Where: Y_t is output, K is physical capital input, and L is labor or human capital input, e^{at} is the production efficiency, while b and 1-b super subscripts, represent the output elasticity relative to labor and physical capital, respectively (Coelli, 2000). The translog cost function is also expressed as:

$$\ln E_i = \beta_0 + \sum_j \beta_1 \ln p_{i,j} + \beta_y \ln y_i + \frac{1}{2} \sum_j \sum_k \beta_{jk} \ln p_{j,i} \ln p_{k,j} + \frac{1}{2} \beta_{yy} \ln y_i \ln y_i + \sum_j \beta_{jy} \ln p_{j,i} \ln y_i + \varepsilon_i \quad (4)$$

Where: E_i is the total production expenditure, $p_{i,j}$ is the price of input j for producer i, and y_i is the output of producer i. The translog cost function or dual cost as it is usually referred to is the quadratic approximation of the unspecified true cost function. These models do relax the restrictions on demand elasticities and elasticities of substitution. The general assumptions are that the cost function must be linearly homogenous, monotonic and concave in input prices.

Definitions of Concepts

Public Policy

Public policy reflects actions of government that are taken to address future occurrence of a societal problem. It refers to broad statements that provide guidelines for actions by government. Public policies are instituted using laws, regulations, decisions, actions, and interventions. Public policy formulation as a decision making tool is defined as a process (Aminu, Tella, & Mbaya, 2012). Similarly, Geurts (2011) defined public policy as a choice that a government makes in response to a political issue or a public problem. Farnsworth (2013) opined that public policy is a process of formulating and implementing different actions, programs, and projects by governments to address a society problem(s) for the overall benefit of citizens. Since it is a process, a public policy cycle comprises four ‘phases’: initiation, formulation, implementation and evaluation.

Efficiency Measure

Efficiency concept is expressed as a ratio of observed output, cost, and profit to potential output, minimum cost and maximum profit frontiers that producers can attain (Baten & Hossain, 2014). In the literature, the three dimensions of efficiency concept that are commonly applied by researchers are technical, allocative, and economic efficiency measures. Gabdo, Abdlatif, Mohammed, and Shamsudin (2014) suggested that a producer is technically efficient if it produces maximum output with a given bundle of inputs. The producer is also assumed to be allocatively efficient when it produces at a point where the marginal revenue is equal to marginal cost. Oluyole, Usman, Oni, and Oduwole (2013) opined that a producer is economically efficient when it achieves an optimum level of output from a given bundle of input at least cost or at maximum level of revenue and/or profit. Therefore, the concept of economic efficiency is defined as a product of technical and allocative efficiencies.

Definition of Variables

The variables in this study were defined for DEA and SF estimations independently. In the DEA models, the variables used for the estimation of technical efficiency scores of rice farms were defined as the pooled physical quantities of rice output and farm inputs obtained from the surveyed states. Specifically the variable inputs were defined as: quantity of fertilizer in kilograms; quantity of planting rice seeds in kilograms, herbicides and insecticides applied but measured in liters; labor input in man-hours, including imputed family labor in man-hours; machine use, measured in man-hour; and quantity of green manure use, measured in kilograms.

Likewise, in estimating the DEA cost efficiency scores, the variables were defined as pooled total cost of production and physical quantity of rice output collected from the rice farming respondents. The cost of inputs was defined as physical quantities of inputs multiplied by the respective input prices. The cost variables were: costs of fertilizer, rice seeds, herbicides, insecticides, green manure, cost of machine man-hour, and cost of labor input. All variables were measured in naira currency (LCU), while the physical quantity of output was measured in kilograms.

Conversely, in the parametric approach (OLS?COLS and SF), the models were specified as log-linear Cobb-Douglas production and translog cost functions, which were regression-based. Therefore, with regards to the estimation of technical efficiency of paddy rice farm households, the variables were categorized into dependent and independent variables. Thus, the variables used to estimate technical efficiency of rice farms were the pooled physical quantity of individual paddy rice farm households' output as the dependent variable and the independent variables were defined as the pooled physical quantities of individual inputs used by the surveyed rice farmers. These inputs include quantity of fertilizer in kilograms, quantity of rice seeds in kilograms, herbicides and insecticides applied measured in liters; labor input in man-hour; machine used in man-hour, and quantity of green manure used measured in kilograms (Schmidt & Knox Lovell, 1979).

Similarly, in estimating the parametric cost efficiency measures, the variables were defined as pooled total cost of production as the dependent variable. The independent variables were the prices of inputs and the physical quantity of rice output collected from the rice farming respondents. The cost of inputs was as before defined as physical quantities of inputs multiplied by the respective input prices. The cost variables were: costs of fertilizer, rice seeds, herbicides, insecticides, green manure, cost of machine man-hour and cost of labor inputs. Thus, the total cost was the summation of all variable input costs used in the model. All variables were measured in naira currency (LCU), while the physical quantity of output was measured in kilograms. The total cost of production and the prices of inputs were normalized by dividing with one of the input prices, thereby eliminating that particular input price from the model. The essence was to ensure that the model met the assumption of linear homogeneity in input prices.

In the second stage, independent variables were measured by policy actions that were regressed against the technical and economic efficiency scores obtained from the first stages. This was intended to explain the impact of policy actions on the respective measures of efficiency. These variables were however, controlled by the socioeconomic factors that were specific to the farms. These independent and control variables were either classified as continuous or categorical variables (Oguntade et al., 2011).

Data Analysis

In a study like this, it is important to take account of the heterogeneity inherent in rice technologies and characteristics of rice farm households by different states. It is perhaps important to note that there are peculiar differences in the resource endowments across the selected states. As such, several steps of data consolidation were implemented to take account of these differences. The most intuitive way of explaining differences in technologies is first to group the rice farmers in subsets. Thus, a multistep analysis was used for the analysis of the cross-section data generated from the survey.

First, was to consolidate the returned data irrespective of the state samples for the analysis. Thus, the consolidated data incorporated all the respondent farmers irrespective of states they belong. In the next step was the consolidation of data by individual state samples for the surveyed states (Kaduna, Nassarawa, and Niger States) for the respective analysis. The essence of these procedures was to enable the verification of possible significant variations in results due to differences in resource endowment.

Data analysis employed different software such as an Excel spread sheet, PIM-DEA Version 3.2 and STATA Version 14.1. The primary data from the field work were organized and some relevant statistic were analyzed using an Excel spreadsheet. The evaluation of farm efficiency scores, first, in the DEA approach used PIM-DEA Version 3.2 software. This uses mathematical programming to solve for productivity performances of producers. The SF models and other regression-based analysis employed the STATA software Version 14.1. This is econometric software that has the capacity to apply all types of regression-based estimators that were used with the dataset.

Assumptions and Limitations

Modeling production activities by economists is a fiction of the complex production process. To be effective in modeling, economists have always made some underlying assumptions that could reduce the complex production decisions of producers to mathematically deduced forms. Therefore, this study relied on this premise and made the following assumptions. First, the study assumed that selected farm households that were engaged in rice production used nonnegative vector of rice farm inputs to produce nonnegative paddy and milled rice output. Second, it was assumed that there is a perfect competitive market in which producing households were operating and therefore were price takers. Third, the study assumed that the farm households obtained a perfect substitute for family labor in local labor market and, conversely it can sell its own labor at a given wage. Hence, the rice farmers were asked to impute the costs of respective family labor used in the paddy rice production.

In addition, it was assumed that profit-maximization dominated the rice production decisions as against utility maximization or risk minimization and therefore, they produced largely for commercial sale (Abdulai & Huffman, 2000). It was also assumed that the rice farmers operated with discretionary inputs and outputs, meaning that all inputs and outputs are within the control of the farm managers. Finally the analytical framework assumed that rice farmers across the federated states had distinct peculiar characteristics and were endowed with varying resources, while the intensity of implementation of the Federal Government Presidential Initiative on rice sector varied among the states.

There were also several limitations that are worthy of mention. First was the application of cross-section data as against the possible use of panel data. Panel data provide information on different time periods that could be useful for understanding how changes had occurred in the technical and economic efficiencies levels of producers over time due to policy actions. Thus, panel data are helpful in evaluating the impact of policies over time. This is in contrast to only one observation point used in cross-section analysis.

Therefore, a cross-section form of data may not be able to expose the impact of policies over a time period in terms of changes in rice farm technical and economic efficiencies levels and how they had improved over time. Second was the assumption that the rice produced was for commercial purpose i.e. cash crop, which was a simplification of the production objective function merely to enable the conceptualization of the production technology (Pollak, 2011).

Significance of the Study

Rice production, processing, distribution and consumption play a crucial role in Nigeria's agricultural model and food security policy. In line with this role, the findings of this study could serve as policy inputs on how best to allocate and utilize resources for raising paddy rice output in Nigeria and in turn milled rice output. The conclusions of this study are expected to be of interest to policy makers in other SSA countries having similar backgrounds and issues (Kyei, Foli, & Ankoh, 2011). In terms of contributions to knowledge, the study will illuminate comprehensive behavior patterns and characteristics of rice farming households, which could be useful in understanding behaviors of entire rural economy of Nigeria.

The results from this study could promote knowledge into the rural economy, which researchers can use as reference point to develop and revise for effective policies. A quick peek on the literature on efficiency and productivity performances in agricultural sector in Nigeria revealed inadequate applications of multiple estimation techniques. In other words, application of comparative analytical techniques used in this study on efficiency and productivity measurements is germane as it could help to reach robust conclusions that may feed into policy making. Overall, the study contributes to social change as outcomes of findings will help to boost local rice production thereby, reducing prices and curbing hunger, disease and poverty.

Conclusion

Nigeria has experienced surge in demand for rice since 1970. The surge in rice demand is attributed to high population growth, increase in per capita income, urbanization and the changing occupational structure of households. The chapter therefore highlighted the major objective behind this study, which was to evaluate the efficiency levels of paddy rice farmers in response to various public policies implemented by the three levels of government in Nigeria to increase local rice production. A quantitative research design and a survey approach were employed, specially using multiple sampling technique and cross-section form of data. In terms of techniques of estimation of level of efficiency, the study applied multiple estimation techniques. The assumptions and limitations of the study were discussed. The chapter highlighted the relevance of the study to policy makers, the academia and the public in terms of social change.

The rest of this dissertation contains the literature review, research method, analysis of empirical results, and discussions of the findings of the study, implications for public policy and social change, and recommendations and conclusions. Chapter 2 sets the agenda for this study, focusing on stylized facts on Nigeria as well as the overview of Nigeria's rice economy and rice subsector policies, the theoretical framework, review of methodology of efficiency measures and analysis, and the empirical literature on rice subsector efficiency measurements.

Chapter 3 presents a detail discussion of research methodology used in this study. Therefore, it explains the research design and survey methodology, sampling strategy and settings, sample size, data collection and instrumentation, validity and reliability of results, ethical considerations, definitions of variables, model specifications, and data analysis methods and procedures. Chapter 4 presents the empirical results of the field study, descriptive statistics covering the characteristics of paddy rice farm households and others, discusses the profitability of paddy rice business, and estimates the efficiency frontiers for the technical and economic efficiency measures. Chapter 5 reveals the findings, interprets the findings of the empirical study, discusses the impact of rice subsector policies on technical and economic efficiency scores across paddy rice farm households in the whole sample, identifies the implications for public policy and social change, makes recommendations and concludes the dissertation.

Chapter 2: Literature Review

Introduction

This chapter presents relevant information about Nigeria, an overview of Nigeria's rice economy and rice subsector policies, the study's theoretical framework, and a review of the approaches to estimating producers' efficiency levels and relevant empirical literature. The theoretical framework exposed the production and efficiency theories, and the economics and the relevance of efficiency analysis. The review of approaches of producers' efficiency estimations identifies the empirical models of the DEA and SF that were used in this study. The discussion of relevant empirical literature includes a review of literature on efficiency measures in the rice subsector, an examination of previous studies on efficiency analysis in the rice subsector from different countries. This includes discussions of the methodology, scope, data collection procedures, results, and conclusions of related literature. Finally, it assesses pertinent methodological issues arising from the empirical literature.

Facts about Nigeria

The section presents information on the geography and structure of Nigeria's economy. It discusses the climatic conditions, vegetation, population, and political divisions of Nigeria. It also reviews the macroeconomic developments, structure, and role of agricultural sector in Nigeria.

Geography and Climatic Conditions

Nigeria is a tropical country located between the equator and Tropic of Cancer. It has a land area of 923,768 km^2 and a coastline of 853 km, and lies on latitude 10^o North and longitude 8^o East. The climatic conditions are determined by south westerlies and north easterlies. The south westerlies contain a lot of moisture, which emanates from Atlantic Ocean but north easterlies are hot and dry winds that come from Sahara desert (Abdulkadir, Usman, Shaba, & Saidu, 2013). Therefore, two distinct seasons are found in the country: dry and wet. The dry season starts around November and ends about March, while the wet season last from April to October (Ozor, Umunakwe, Ani, & Nnadi,2015).

However, the climatic conditions vary between southern and northern parts of Nigeria(Macaulay, 2014). As a result, rainy season occurs between March and November each year in the south, while in the northern part, it starts in July and ends around September. Similarly, dry season period in the southern part of the country begins in November and lasts until March, while in the north it runs between October and May in each year. The average temperature per year is 26.4 °C (80 °F) and the average annual rainfall is 1,626 mm (64.0 in), with an average of 121 days of rainfall per year. Average annual relative humidity is about 84.7%, with an average of 1,885 hours of sunlight per year (Oluyole et al., 2013).

There are different types of major soil zones in Nigeria, with significant variations between southern and northern locations (Oku, 2011). Common soil types in the northern part of Nigeria are loose sandy soils (consisting of wind-borne deposits) and river sands.

Clay soils can be found towards the riverine areas of southern zone. According to official estimates, agricultural land area in Nigeria is about 79 million hectares, constituting 85.9% of total land area of 92 million hectares. Of the 79 million arable land area, only about 34 million or 42.0% is currently been cultivated for all crops, livestock, and forestry products (Nwanakoala & Osigwe, 2013). Forest and savannah are the main vegetation types commonly found in the country, with their distribution affected by rainfall distributions and patterns, and human activities such as bush burning, cultivation, tree harvesting, and cattle grazing (Ladan, 2014).

Population and Political Divisions

Nigeria had an estimated population of 171.6 million people in mid-2013, representing approximately 18.8% of sub-Saharan Africa's total population (World Bank, 2014). Nigeria has a federal constitution and has one central government, 36 federated states, one Federal Capital Territory (FCT) and 774 local councils. The country is divided into six geopolitical zones: south-east, south-west, south-central, north-central, north-east and north-west zones (Federal Republic of Nigeria [FRN], 2004). All tiers of government are dependent on oil revenue, which accounts for about 80% of general government revenue (CBN, 2012).

Macroeconomic Environment

Nigeria has the largest economy in Africa and, at the time of this study, the 26th-largest economy in the world (National Bureau of Statistics [NBS], 2014). Nigeria is currently the biggest oil producer in Africa, the 7th-largest oil producer in the

Organization of Petroleum Exporting Countries (OPEC), and the 13th-largest producer in the world (OPEC, 2013). The country's gross domestic product (GDP) was estimated at approximately U.S. $509.9 billion in 2013. Real income per capita was also estimated at US $2,258 per annum. Real economic growth has also been robust at an average annual growth rate of 6.2% between 2004 and 2013 (NBS,2013). In terms of sectoral contributions to real economic growth, the share of services sector to GDP in 2013 accounted for 51.1%; agriculture and industrial sectors had shares of 23.3% and 11.2%, respectively. The crude oil and natural gas sector's contribution to economic growth was 14.4% (CBN, 2013).

Agriculture and Nigerian Economy

The Nigerian economy was predominantly agriculture prior to the emergence of crude oil and natural gas sector in 1970, contributing more than 40.0% of GDP. Although agriculture remains very vulnerable, it still accounted for about 70.0% of total employment (African Development Bank Group [AfDB], 2014). Between 1960 and 2013, agricultural sector recorded an average annual growth rate of 6.5%. The sector remained the major supplier of food and raw materials to industries and generates family incomes for majority of the population. According to Akpan (2012), agricultural sector in Nigeria is however, dominated by smallholder producers who are operating farm sizes of not more than 1 to 5 hectares. However, these smallholder farmers accounted for over 90.0% of agricultural output.

The sector comprised different subsectors: cash crops, forestry or tree crops, fisheries, food crops, and livestock. The food crops subsector remained the dominant crops produced and these include cereals (sorghum, millet, maize, and rice), tubers (cassava, yam, and cocoyam), vegetables and horticultural products. Although Nigeria leads the world in production of yams and cassava, it lags behind the rest of the world in the production of many cereal crops (FAOSTAT, 2013). To this extent, the country is heavily dependent on importation of cereals to meet domestic supply-demand gap. Massive rice importation is more feasible in the total cereals importation.

Nigeria's Rice Value Chain

The section examined the structure and performances of Nigeria's rice value chain. For example, it identified participants in the rice economy and analyzed performances of the rice value chain in terms of the structure and trends of consumption and production. It further exposed the constraints facing the rice subsector in Nigeria and explained the supply-demand dynamics of the rice subsector.

Structure of the Rice Value Chain

Nigeria's rice subsector is represented by a rice value chain, which is similar to value chains of agricultural commodities produced and marketed domestically. A rice value chain is conceptualized as a process of value-adding activities through production to consumption of rice commodity. Therefore, an analysis of rice value chain entails an investigation into how rice is produced, processed, marketed, and consumed. This study, however, specifically focused on rice production and consumption. The value chain shows the important participants involved in the production to the consumption of milled rice and allied products.

Practical discussions of commodity value chains in agricultural business and production management use two relevant models namely: Porter's model and the global commodity chain (GCC) model (Smit, 2010; Bockel, & Tallec, 2005). Porter's model and the GCC model are used to develop strategies for commodity production and improvement in producers' efficiency levels of different actors in an agricultural commodity value chain (Maneechansook, 2011). Thus, the value chain concept is based on a pricing strategy,cost structure, and participants' profit margins. Each actor in a value chain depend on his/her organizational performance to survive. In terms of Nigeria's rice economy, activities in the subsector can be classified into primary activities (farm production) and secondary activities (processing, milling, packaging, and marketing).

A commodity value chain is therefore categorized into two broad control systems:

- Producer control chain meaning that producers have ultimate control of all the networks and activities in the value chain.
- Buyer control chain implying that distributors/marketers control all networks and activities in the value chain.

Table 3

Comparison of Value Chains of Raw and Parboiled Rice

No.	Raw Rice	Parboiled Rice
1	Farmers produce paddy rice supported by many government agencies.	Farmers produce paddy rice supported by many government agencies.
2	Farmers harvest rice, thresh, pre-dry and store rice as long as 3 years or when they need cash.	Farmers harvest rice, thresh, pre-dry and store rice as long as 3 years or when they need cash.
3	Farmers sell paddy to local traders for cash and hold the paddy for at most one week.	Farmers sell paddy to local traders for cash and hold the paddy for at most one week.
4	The local traders' cash sell the paddy rice to wholesalers who transport them to the towns.	The local traders' cash sell the paddy rice to wholesalers who transport them to the towns.
5	The wholesaler also cash sell paddy rice paddy to a major distributor in towns.	The wholesaler also cash sell paddy rice paddy to a par boiler.
6	Not Available	Par boiler proceeds parboil the paddy.
7	The wholesaler outsources the milling of the paddy rice to rice or use own mills.	The par boiler proceeds to outsource the milling of the parboiled paddy to a miller or decide to mill it through own mills.
8	Not Available	The milled rice is cash sell to the wholesalers/distributors.
9	The wholesaler sells the milled rice to the retailers.	The wholesaler sells the milled rice to the retailers.
10	The retailer sells the milled rice to final consumers.	The retailer sells the milled rice to final consumers.

Note. Adapted from ‘’ Improved Quality of Rice Processing (NIG 225): Nigeria Farmer-to-Farmer Program’’ by Tinsley, 2011, Winrock International, July.

There are two broad categories of the rice value chain in Nigeria: raw rice and parboiled rice value chains. Table 3 explained the two value chains, showing the presence of a large number of distribution/marketing networks in each value chain. Rice value chains for raw and parboiled rice begin with the paddy rice farmers and end with the final milled rice consumers. Table 3 further explained the presence of many intermediaries within the different rice value chains in Nigeria. Tinsley (2012) opined that each of the Nigerian rice value chain is dominated by the powerful distributors with a large number of smallholder farms and mills. Along this value chain are governments' institutions providing policy support and other services. The dominance of distributors/marketers in each of the rice value chain thus, makes the value chains *buyer driven*.

Hence, the value chains are characterized by: (1) most transactions are for immediate cash, because the farmers are poor and operate with limited cash overhead, and (2) the presence of high cost of labor and other overheads. The presence of buyer- driven rice value chains is considered by researchers as the major cause for the inability of rice farmers to achieve higher production and cost efficiencies levels over time. The earnings from the farms are considerably little compared to the efforts in the farms and this has acted as the main disincentive to higher output (Tinsley, 2011).

Paddy Rice Production Systems

Nigeria has four rice production systems namely: upland rice, lowland rice, irrigated rice and mangrove/deep water rice production systems (Ogunsumi, Ajayi, Amire, & Williams, 2013). In the upland rice ecology, production strictly relies on amount of rainfall during the cropping season. The system is characterized with limited use of modern farm inputs (fertilizers, herbicides and modern technology). Farm practices are dominated by significant intercropping and fallowing, while farm sizes range between 1 to 5 hectares (Erenstein, et al, 2003). They are cultivated in central Guinea savannah (semi humid zones) and in northern Sudan savannah (semiarid zones). However, a handful of rice farmers cultivate paddy rice using limited irrigation systems that depend on nearby rivers and streams. Yield per hectare in this system is low but they perform better in the southern part of the country because of higher number of rainfall days (Fakayoade, 2009). Paddy rice yield is an average of 2.1 tons per hectare, while it accounts for an estimated 60.1% of total rice land area harvested in Nigeria. It is also responsible for about 41.0% of national rice output (see Table 4).

The lowland rice production system is found in waterlogged lowlands with variable flood levels. In the system, water control is nonexistent but modern farm inputs (fertilizers, pesticides, herbicides, improved rice seeds and modern technology) are moderately used. Rice cultivation under this system is grown also in small farm sizes of between 1 to 5 hectares and it is dominated by small family rice farmers. Rice cultivation is by direct seeding, broadcast or transplanting from nursery. As in the upland area, cultivation of a single-year crop season is the common practice (Idiong, Onyenweaku, Ohen, & Agom, 2007). Average yield is about 3.9 tons per hectare, while its contribution to domestic national output is 42.0%, and its share of rice land area cultivated is 18.2%.

The mangrove and deep water (floating) rice production system is found along the coastal parts of Nigeria and lies between the coastline and fresh water swamps. The system contributes about 13.4% of the national rice production area. At 0.9 metric tons per hectare, yields are lowest compared to other systems, while its contribution to national output is about 7.3%.

Table 4

Rice Production Systems in Nigeria

Types	Area Planted (Hectares)	Rice Output (metric tons)	Yield (MT/ha)	Area Share %	Production Share %
Upland	675,160.9	778,707.1	2.1	60.1	41.0
Lowland	203,884.2	798,991.0	3.9	18.2	42.0
Irrigation	92,719.1	184,117.0	3.2	8.3	9.7
Mangrove	150,883.3	138,655.1	0.9	13.4	7.3
Total	1,122,647.5	1,900,470.1	2.5	100.0	100.0

Note. Adapted from ‘’. Rice Data Systems in Nigeria: Building a Rice Data System for Sub-Saharan Africa (National Rice Survey 2009)’’ by Ojehomon, V. E. T., S. B. Adebayo, O. O. Ogundele, V. O. Okoruwa, O. Ajayi, A. Diagne, and O. Ogunlana, 2009, Ibadan, Nigeria: NCRI (National Cereals Research Institute), National Bureau of Statistics (NBS), Nigerian Institute of Social and Economic Research (NISER), and University of Ibadan, p.39. Mt/ha = yield in metric tons per hectare.

Irrigated rice ecology is also characterized by a wide array of rice-based production systems. It includes systems with complete water control in Sahel and Sudan savannah zones in northern part of the country, and systems with partial water control found in some parts of savannah and equatorial zones in the middle belt and south-eastern parts of the country. In these systems, wide diversities in land and resource endowments exist. The diversities range from small farmers who have access to less than one hectare to large-scale producers cultivating more than one hundred hectares. It is characterized by supply of water from rivers, wells, boreholes and other sources to supplement rainfall. The system is also partially dominated by multiple-year cropping seasons as rice cultivation takes place about two times a year (Jamala, Shehu, & Garba, 2011). It covers an estimated 8.7% of cultivated rice land and its average yield is about 3.2 metric tons per hectare, while it contributes about 9.7% to national rice output.

These rice production systems are spread across 36 states and FCT. Most of the states have comparative advantages in one or more production systems. Table 5 presents dominant rice production systems in each state of Nigeria. The upland production system is widespread as almost all states have comparative advantages in producing rice from rain-fed and dry upland systems. Within the upland production system, the hill rice cultivation is spread in Ekiti, Benue, Borno, Nassarawa and Zamfara states. An important feature of rice cultivation in upland rice production system is intercropping of rice with maize, millet, beans, okra, yam, etc.

The lowland production system takes a second position as it is found in about 19 states. The lowland systems include broad valley bottoms or '*fadama'* (lowlands) in the north, and the flood plains along the Rivers Niger and Benue troughs and other minor watercourses and tributaries along these rivers' drainage systems. Fadama type soils are waterlogged rice fields and they are widespread among states in the north. They are found mostly in the guinea savannah vegetation zone or in north-central and partially in north-western zones. These are found in Niger, Benue, Kaduna, Katsina, Kebbi, Kogi, and Kwara states. The flood plains of River Niger and its tributaries also provide good ecological conditions for fadama rice cultivation in Anambra, Akwa-Ibom, Bayelsa, Cross River, Ebonyi, Delta, and Rivers states (Fakayoade, 2009). The fadama type soil rice fields are also found in north-eastern zone of the country near the flood plains of Lake Chad Basin in Borno State and along River Benue flood plains in Adamawa State (Jamala et al., 2011).

Irrigation schemes became relevant agriculture facilities in Nigeria since 1970s and where developed following Asian Green Revolution example. These irrigation schemes are complimentary measures taken by governments towards intensification of irrigated agriculture in general and rice production in particular. These schemes provide water all year-round to farmers making it possible for multiple cropping (Dauda et al., 2009). These are found in some states and are most relevant in the northern part of the country due to shortness of rainy season.

Most of the irrigation schemes found in the country are: individual farmers' pump irrigation with water obtained from shallow tube wells dung by farmers, small to medium-scale community-based pump irrigation from deep wells shared by community farmers, small-to-medium-scale community-based surface irrigation with water diverted from ponds or reservoirs or from near-by rivers and large-scale surface irrigation where water is diverted from reservoirs or lakes (Liangzhi et al., 2010). Several small, medium and large or community/local governments based irrigation schemes have also been constructed by the state and local governments in support of rice farmers (see Table 5).

Among the states with such schemes are: Jigawa State (Hadeija valley irrigation project, 1981; Jekarade irrigation and Dambo irrigation schemes), Borno State (Yau irrigation scheme, 1959; Jere Bowl, 1948; Abadam irrigation, 1957 and Chad Basin irrigation scheme, 1973), Enugu State (Adani rice irrigation scheme, 1978), Ebonyi (Ezillo community irrigation farms), Kebbi (Sokoto Rima Basin, 1975; Zauro Polder Project) and Kwara (Duku/Lade irrigation scheme, 1985). Others include: Abia State (Bende irrigation scheme, 1970), Kano State (Kano River irrigation scheme at Kadawa, 1970), Sokoto (Bakolori Dam irrigation in Sokoto River valley, 1979), Niger State (Badeggi irrigation scheme located in Bida in Musa River valley, a tributary of River Niger, 1950), and Zamfara (Saba and Talata irrigation schemes). There are also many small dams and tube wells that are constructed within the large schemes by farmers and communities.

Table 5

Distribution of Rice Production Systems by States

Production Systems	States
Upland	Abia, Bauchi, Benue, Borno, Delta, Ebonyi, Edo, Ekiti, Enugu, Gombe, Jigawa, Imo, Kaduna, Kastina, Kebbi, Kwara, Kogi, Nassarawa, Niger, Ogun, Ondo, Oyo, Osun, Sokoto, Plateau, Yobe, Zamfara, Taraba, and FCT.
Lowland (Fadama)	Adamawa, Anambra, Akwa-Ibom, Bayelsa, Borno, Delta, Cross-River, Ebonyi, Edo, Enugu, Kaduna, Katsina, Kebbi, Kwara, Lagos, Nassarawa, Ondo, Osun, and Rivers.
Irrigation	Adamawa, Benue, Borno, Cross River, Ebonyi, Enugu, Kano, Kebbi, Kwara, Lagos, Niger, Ogun, Sokoto, and Zamfara.
Mangrove/Deep Water	Flooded Rima River Valley areas-Kebbi State and deep flood areas of Delta State. Other states are: Ondo, Edo, Rivers, Bayelsa, Cross-River, and Akwa-Ibom.

Note. Compiled based on data from the Federal Ministry of Agriculture and Rural Development (2011), Cadoni & Angelucci (2013) and Fakayoade (2009).

Mangrove and deep water or swamp rice production systems are found around coastal states of Nigeria and it is the oldest form of rice cultivation culture in the country. They are found around flooded plains of Rima River valley in Kebbi State, and deep flood plains of Akwa-Ibom, Cross River, Delta, Edo, and River States. The success factor in mangrove swamp rice cultivation is linked to length of salt free period. Therefore, feasibility and success of growing rice in mangrove swamp are linked to the ability of farmers to recognize and separate soils with salinity and acidic problems and to use modern methods to manage the fields for higher output (Balde et al., 2014).

Trends and Structure of Rice Consumption

Milled rice is widely consumed in Nigeria as household food item and also is used by industries to produce other rice-based food and pharmaceutical products (Alfred & Adekayode, 2014). In some instances, the paddy rice is used in the production of animal feedstock. Thus, the major industrial rice consumers in Nigeria are food and drink industries (for example, pasta and bread industries, beer and other liquor distilleries), and pharmaceutical companies. Nigeria recorded steady growth in demand for rice by households, industries and livestock feeds manufacturers since 1970. The Nigerian consumers consume different types and grades of rice. At household level it is consumed as boiled or fried with stew or it is used to prepare special dish such as ‘tuwo’.

However, different cultures in Nigeria have distinct preferences regarding taste, texture, color and stickiness of rice varieties that they consume (Oko, Ubi, & Dambaba. 2012). Thus, Nigeria consumers’ preferences of rice varieties particularly local milled rice are linked to the grain and cooking qualities. The rural population consumes more of locally milled rice and in particular *ofada* rice. However, preference is different with urban population preferring imported rice, especially long grains. Rice consumption by households increased consistently since 1970s and is now an important staple cereals and food item in households' food expenditure (see Table 6).

Table 6

Selected Indicators of Rice Consumption in Nigeria

	Consumption (MT)	Growth Rate (%)	Share of W/A (%)	Per Capita (KG)	Growth Rate (%)
		Nigeria			
1960-1969	246.8	1.7	16.9	4.9	-2.3
1970-1979	505.6	13.7	52.7	7.6	7.9
1980-1989	1262.5	8.0	53.0	14.9	1.8
1990-1999	2432.5	8.8	35.5	22.4	1.8
2000-2009	3744.7	4.9	38.0	26.9	0.6
2010-2013	5102.3	4.3	40.0	31.0	1.6
2014	5558.0	2.5	40.1	31.5	-0.4
		West Africa			
1960-1969	1458.5	5.5		12.9	3.2
1970-1979	2398.0	7.8		16.9	5.4
1980-1989	4589.2	5.2		25.6	2.0
1990-1999	6852.6	3.2		29.1	0.8
2000-2009	9125.8	3.5		32.4	1.1
2010-2013	10964.9	3.1		35.2	1.3
2014	13849.3	4.0		36.5	1.5

Notes. Data sourced from International Rice Research Institute [IRRI] Database. Retrieved from http://ricestat.irri.org:8080/wrs2/entrypoint.htm. The population data used was obtained from World Development Indicators, 2013. Retrieved from http://creativecommons.org/. The consumption data is presented in thousand metric tons. The consumption per capita, was defined as the total annual consumption divided by the annual population and it is given in kilograms per year, and W/A means West Africa.

Milled rice consumption by households grew from an average of 0.3 million metric tons per annum in 1960s to 0.5 million metric tons per annum in 1970s. This represents an average annual growth of 13.7% per annum. Although the average annual rate of increase slowed down after 1970s, however the annual increase in the quantity of milled rice consumed has persisted. Total consumption increased to an average of 5.1 million metric tons in 2010-2013 period, representing an average increase of 4.3% per annum. Total volume of rice consumption in 2014 was estimated at 5.6 million metric tons, representing an increase of 2.5% over the level in 2013 (see Table 6).

The increase in consumption of rice in Nigeria is better appreciated from an analysis of the trend in per capita consumption in the past five decades. Per capita consumption increased consistently from an average of 4.9 kg per year in 1960s to an average of 22.4 kg per year in 1990s. Per capita consumption accelerated to 31.0 kg between 2010 and 2013 period and increased marginally to an estimated 31.5 kg per year in 2014. The persistent increase recorded in per capita consumption thus far, showed that rice product has become a major food staple, while this trend is anticipated to continue over the next four decades (Ogunsumi et al., 2013; Adesina, 2012).

In terms of West-Africa sub region rice consumption, Nigeria remained the biggest consumer of rice in the sub region. A comparative analysis showed that consumption of rice by consumers in Nigeria accounted for about 16.9% of the 1.5 million metric tons of rice consumed in the sub region in 1960s. This increased to an average of 52.9% of the 3.4 million metric tons of rice consumed by sub regional consumers in 1970s and 1980s. By 1990s, the share dropped substantially to 35.5% of 6.9 million metric tons, while it rose to 40.0% of 12.8 million metric tons sub regional total consumption between 2010 and 2013.

This increased further slightly to 40.1% of the estimated 13.8 million metric tons of rice consumed in the sub region in 2014 (see Table 6).

The persistent increase in per capita consumption is attributed to a combination of factors such as rising population, growth in per capita income, rapid urbanization and changes in occupational structure of citizens, which induced changes in food preferences by working and urban housewives (GAIN, 2012). For example, in the past five decades, Nigeria witnessed rapid increase in population. The population grew from 45.9 million in 1960 to 171.6 million people as at mid-2013 (U.S. Population Reference Bureau, 2013), representing an average annual increase of 2.5%.

Table 7

Population Growth and Rice Consumption

Years	Annual increase in population	# of times	Annual increase in consumption	# of times
1960-1969	2.2	1.0	1.6	3.6
1970-1979	2.7	1.3	13.7	2.5
1980-1989	2.6	0.9	8.0	25.0
1990-1999	2.4	0.9	8.8	0. 0
2000-2010	2.5	1.1	5.5	1.2
2011-2013	2.7	1.1	3.5	7.6
1960-2013	2.5	1.3	7.2	5.3

Notes. Data sourced from International Rice Research Institute [IRRI] Database. Retrieved from http://ricestat.irri.org:8080/wrs2/entrypoint.htm, and United States Population Reference Bureau. (2013). World Population Data Sheet. Retrieved from http://www.prb.org/pdf13/2013-population-data-sheet_eng.pdf. The number of times was calculated as the growth rate in 2013 divided by the growth rate in 1960.

According to Population Action International (2011), ‘’increasing numbers of people often drive up demand for food, which results in additional use of agricultural land and water’’ (p.1). Population growth in Nigeria is associated with demand for additional food inclusive of rice product. Table 7 showed a simple relationship between rising population and increase in rice consumption in Nigeria. The country recorded an average increase of 2.5% per annum in population, meaning an increase of 1.3 times in population between 1960 and 2013. This perhaps induced an average increase of 7.2% per annum or 5.3 times of households’ rice consumption in the same period. This was even more visible during 1970s through 1990s, as annual increase in consumption of rice of 10.1% could be traced to the average annual increase in population of 2.6% per annum in the same period.

Table 8

Growth in Per Capita Income and Rice Consumption

Years	Annual increase in per capita income	# of times	Annual increase in per capita consumption	# of times
1960-1969	3.2	0.2	1.6	3.6
1970-1979	14.9	0.2	13.7	2.5
1980-1989	16.3	3.7	8.0	25.0
1990-1999	28.7	0.8	8.8	0.02
2000-2010	30.9	1.0	5.5	1.2
2011-2013	11.0	0.7	3.5	7.6
1960-2013	21.2	2.3	7.2	5.3

Note. Data sourced from International Rice Research Institute [IRRI] Database: Retrieved from http://ricestat.irri.org:8080/wrs2/entrypoint.htm and CBN, database: Retrieved from http://www.cenbank.org

Nigeria has also experienced significant increase in gross national income translating to higher income per capita. In the literature, the relationship between per capita income and per capita food consumption is anchored on consumer behavior theory. The consumer behavior theory assumes that consumers allocate limited money income among available goods and services, which is aimed at maximizing utility. Therefore, as income rises, per capita food consumption is expected to increase (MacInnis, 2011). Omojola et al. (2006) suggested that the increase in consumption per capita of rice in Nigeria is attributed to increase in income per capita. They further suggested that the increase over the years was even more relevant with the consumption of foreign rice, thus indicating that rice is a *normal good*. According to Johnson et al. (2013), income elasticity of rice consumption in Nigeria is estimated at 0.63 and was found to be higher in rural sector compared to urban areas.

Table 8 explained a formal relationship between per capita income and rice consumption in Nigeria. Between 1960 and 2013, Nigeria recorded an average increase of 21.2% per annum in nominal per capita income or about 2.3 times. This induced an average growth of 7.2% per annum or 5.3 times in rice consumption by households. The increase in demand for rice was however, prominent in 1970s as demand for rice rose by an average of 13.7% per annum or 2.3 times in reaction to less than 1 time or 14.9% annual increase in per capita income.

The increase in rice consumption in relation to per capita income so far can be visualized formally, by comparing the budget share of rice consumption in food basket that is the amount of household income spent on purchasing rice product. The budget share (BS) of a consumer good is clearly defined as price of the commodity multiplied by quantity consumed divided by total consumer spending or income (Cirera & Masset, 2010). According to NBS Consumption Pattern Survey (2012), rice consumption among all staples and total food purchases occupied the fifth position and accounted for 9.9% and 8.9%, respectively. In terms of budget share, it accounted for 5.8% of total consumer spending. While rural consumers spend about 10% of their total income on rice, urban consumers spend about 9.8%.

Rapid urbanization in Nigeria also accounted for major changes in lifestyles of citizens, leading to shifts in preferences or taste in favor of rice meals. Nigeria has experienced high rural-urban migration and the aftermath were changes in occupational structures of many households and increased involvement of women in the workforce (Ango, Ibrahim, & Alhaji, 2014). Thus, the relative ease of preparing rice meals compared to other traditional cereals thus, had contributed immensely to the shift in preferences for rice meals from other traditional staples.

Trends and Structure of Rice Production

Nigeria since 1990s, recorded substantial increase in local rice production however, the increase has not been sizeable enough to cover the growing local rice demand. For example, output of paddy rice increased from an average of 0.4 million metric tons in 1960-69 period to an average of 4.5 million metric tons per annum in 2011-2013 period. The increase between 1960 and 2013 period reflected an average growth rate of 6.1% per annum. The growth in paddy rice output was however more significant in the 1980-1989 period, recording an average increase of 22.6% per annum. Between 1990 and 1999, the annual increase of paddy rice production however slowed down to 1.1% (see Table 9). This dismal performance of the sector during this period was traced to policy inconsistency in trade policies (Iwuchukwu & Igbokwe, 2012). However, paddy rice production recovered marginally and grew by an average of 3.3% per annum in 2000-2010 periods.

Table 9

Indicators of Rice Production in Nigeria

	Nigeria		West Africa		% Share of Nigeria	
Years	Paddy Rice	Milled Rice	Paddy Rice	Milled Rice	Paddy Rice	Milled Rice
1960-1969	369.6	245.7	1,725.6	1,150.4	21.9	21.8
1970-1979	536.0	356.5	2,548.2	1,698.8	21.1	21.1
1980-1989	1,355.0	866.1	4,171.1	2,780.8	30.6	29.6
1990-1999	3,029.9	1,817.9	6,397.7	4,265.1	47.3	42.6
2000-2010	3,558.7	2,194.9	8,762.6	5,841.8	41.0	37.8
2011-2013	4,451.1	2,852.4	12,290.5	7,634.4	36.8	37.4

Notes. Data sourced from International Rice Research Institute [IRRI] Database: Retrieved from http://ricestat.irri.org:8080/wrs2/entrypoint.htm. The production figures are recorded in thousand metric tons. 2013 are author's estimates and will be updated later

Despite the growth in paddy rice production, percentage of paddy rice milled has remained low and accounted for an average of 63.8% per annum of total paddy rice during the period 1960 to 2013. This relative small share of milled rice to paddy rice output suggests large wastages at milling and processing segments of the rice value chain. This is attributed to poor *Head Rice Yield* supplied to mills, which is the most important quality parameter to millers (Asante et al., 2013). In terms of rice production in West Africa sub region, Nigeria was the largest single producer of rice. Between 1960 and 2013, average annual production of paddy and milled rice in Nigeria accounted for 36.8% and 37.4% of total sub regional paddy and milled rice productions, respectively.

Table 10

Regional Contributions to National Rice Output

	Output in Thousand Metric Tons					
Regions	2000	2005	2010	2011	2012	2013
North-East	672.3	727.1	846.2	876.6	922.2	970.2
North-West	966.2	1,045.0	1,216.1	1,259.8	1,325.4	1,294.2
North-Central	1,192.9	1,290.2	1,501.5	1,555.4	1,636.4	1,591.5
South-East	211.4	228.6	266.0	275.6	289.9	305.0
South-West	130.0	140.6	163.6	169.5	178.3	187.6
South-South	109.4	118.3	137.7	142.6	150.1	157.9
Federal Capital Territory	15.8	17.1	19.9	20.6	21.7	22.8
Total	3298.0	3567.0	4151.0	4300.0	4524.0	4529.2

Note. Adapted from ‘’. Rice Data Systems in Nigeria: Building a Rice Data System for Sub-Saharan Africa (National Rice Survey 2009)’’ by Ojehomon, V. E. T., S. B. Adebayo, O. O. Ogundele, V. O. Okoruwa, O. Ajayi, A. Diagne, and O. Ogunlana, 2009, Ibadan, Nigeria: NCRI (National Cereals Research Institute), National Bureau of Statistics (NBS), Nigerian Institute of Social and Economic Research (NISER), and University of Ibadan, p.39. The production data for 2013 are author’s estimates.

A review of states’ rice output produced showed wide disparities across the federated states. Those states within the rich plains of major rivers and subsidiaries such as River Niger, River Benue and Chad Basin, which provide excellent conditions for rice cultivation have continued to dominate in paddy and milled rice production (see Appendix

A). Thus, Kaduna State accounted for 20.2% of national paddy rice output. The second biggest producer was Niger State (16.0%), while the share of Benue State as the third largest producer was 9.8%. Similarly, Taraba State held the fourth position and accounted for 6.8% of national rice output. In terms of geopolitical zones, the North-Central geopolitical zone contributed 35.2% to national rice output (see Table 10). The contributions of other remaining zones were: North-West (28.6%), North-East (21.4%), South-East (6.7%), South-West (4.1%) and South-South (3.5%).

Table 11

Contributions of Production Systems to National Output in thousand metric tons

System	2000	2005	2010	2011	2012	2013	Average 2000-2013
Upland	1,352.2	1,462.5	1,701.9	1,763.0	1,854.8	1,951.3	1,536.6
Lowland	1,385.2	1,498.1	1,743.4	1,806.0	1,900.1	1,998.9	1,574.0
Irrigation	319.9	346.0	402.6	417.1	438.8	461.6	363.5
Mangrove	240.8	260.4	303.0	313.9	330.3	347.4	273.6
Total	3,298.0	3,567.0	4,151.0	4,300.0	4,524.0	4,759.2	3,747.7

Note. Adapted from ‘’. Rice Data Systems in Nigeria: Building a Rice Data System for Sub-Saharan Africa (National Rice Survey 2009)’’ by Ojehomon, V. E. T., S. B. Adebayo, O. O. Ogundele, V. O. Okoruwa, O. Ajayi, A. Diagne, and O. Ogunlana, 2009, Ibadan, Nigeria: NCRI (National Cereals Research Institute), National Bureau of Statistics (NBS), Nigerian Institute of Social and Economic Research (NISER), and University of Ibadan, p.39. The production data for 2013 data are author’s estimates.

A review of paddy rice output between 1960 and 2013 showed that the lowland and upland cultivation systems accounted for an average of 42.0% and 41.0%, respectively, of the national rice output. However, the irrigation cultivation system share was low compared to other developed countries, accounting for only 9.7% of the total national paddy rice output. Similarly, the deep water/mangrove cultivation system had a share of 7.3% in national rice output (see Table 11).

Gray, Oss-Emer, and Sheng (2014) opined that expansion in land area, increase in yield per hectare, intensification in agricultural cultivation, increase in research on new varieties of seeds, adaptation of new technologies, expansion in irrigation system, and increased public expenditure in agriculture as a percentage of GDP were responsible for the growth in agricultural productivity in Central Asian countries.

Table 12

Trends in Rice Area Harvested in Nigeria

Year	Thousands of Hectares	% Growth Rate	% Share of Potential
1960	185.0	0	3.8
1965	210.0	4.0	4.3
1970	254.0	8.5	5.2
1975	300.0	5.3	6.1
1980	550.0	37.5	11.2
1985	710.0	6.0	14.5
1990	1,208.0	-26.9	24.7
1995	1,796.0	4.8	36.7
2000	2,199.0	0.4	44.9
2005	2,450.0	4.3	50.0
2010	2,150.0	2.4	43.9
2011	2,170.0	0.9	44.3
2012	2,250.0	3.7	45.9
2013	2,301.8	2.3	47.0

Note. Data sourced from International Rice Research Institute [IRRI] Database. Retrieved from http://ricestat.irri.org:8080/wrs2/entrypoint.htm.

Chiefly, a combination of these factors such as significant expansion in rice area harvested, increased yield through new high yielding varieties of rice and increase in input supplies by government were responsible for the expansion in paddy rice output in Nigeria (CBN, 2012). Table 12 showed the trend in utilized rice land area between 1960 and 2013. The total land area used for rice cultivation increased from an approximately 185,000 hectares or 3.8% of potential rice land area in 1960 to 2.3 million hectares or 47.0% in 2013. This was an average annual increase of 5.7% of rice land cultivated during the period. The persistent interventions such as the construction of dams, land clearing and tractor hire services contributed to the increase recorded in rice land area harvested.

Table 13

Distribution of Rice Area Harvested across the Production Systems

	Area Harvested in Thousand Hectares				
Year	Upland	Lowland	Irrigated	Mangrove	Total
1960	111.2	33.7	15.4	24.8	185.0
1965	126.2	38.2	17.4	28.1	210.0
1970	152.7	46.2	21.1	34.0	254.0
1975	180.3	54.6	24.9	40.2	300.0
1980	330.6	100.1	45.7	73.7	550.0
1985	426.7	129.2	58.9	95.1	710.0
1990	726.0	219.9	100.3	161.9	1,208.0
1995	1,079.4	326.9	149.1	240.7	1,796.0
2000	1,321.6	400.2	182.5	294.7	2,199.0
2005	1,472.5	445.9	203.4	328.3	2,450.0
2010	1,292.2	391.3	178.5	288.1	2,150.0
2011	1,304.2	394.9	180.1	290.8	2,170.0
2012	1,352.3	409.5	186.8	301.5	2,250.0
2013	1,383.4	418.9	191.0	308.4	2,301.8

Note. Data sourced from various statistical reports by NBS from 1960 to 2013

Furthermore, Table 13 revealed that the upland production system associated with hill side rice cultivation and rain fed system accounted for 60.1% of total rice area harvested. The lowland system accounted for 18.2%, while the mangrove/deep water system accounted for 13.4%. The least contribution came from the irrigated system, which accounted for 8.3%.

Table 14

Indicators of Rice Production Inputs Used

	Average Yield Metric Tons Per Hectare	Fertilizer Consumption 000 MT	Agriculture Expenditure 2005, $	Agriculture Expenditure Per capita	Agriculture R&D as Share of (%) Agriculture GDP
1960-1969	1.8	4.7	n.a	n.a	n.a
1970-1979	1.7	46.7	n.a	n.a	n.a
1980-1989	1.7	252.9	148.1	1.8	0.2
1990-1999	1.7	285.2	117.8	1.1	0.1
2000-2010	1.6	198.9	360.1	2.5	0.4
2011-2013	2.2	203.3	1135.4	6.8	0.9

Notes. Data sourced from International Rice Research Institute [IRRI] Database. Retrieved from http://ricestat.irri.org:8080/wrs2/entrypoint.htm and ASTI (Agricultural Science and Technology Indicators), 2010–11, ASTI database. Retrieved from http://www.asti.cigar.org/data/

The increase in average yield per hectare also induced expansion of paddy rice output in Nigeria. Current national average rice yield is estimated at 2.5 metric tons per hectare although lower than world rice average yield of 4.1 metric tons per hectare, reflecting a substantial yield gap in Nigeria (see Table 14). The intensification of research on new rice seed varieties justified the gradual improvements in yields (Cadoni et al., 2013). So far, several rice seeds have been commercialized by the West African Rice Development Association (WARDA) tagged New Rice for Africa (NERICA) for different production systems. The application of new rice seeds also encouraged the increase in average yields in farms recorded from about 1 metric ton per hectare to about 1.5 metric tons without additional inputs, but yields were higher in cases of irrigated rice cultivation or with the use of fertilizer and other chemical inputs (African Rice Centre, 2012).

Similarly, NCRI has also developed and released several varieties of rice seeds with good properties of paddy rice yield, head rice yield, and swelling capacity, amylase content, protein and cooking time (Ekeleme et al., 2008). These efforts were possible through increased funding of research activities in rice seed varieties. For example, total real expenditure on agricultural research by both the public and private sectors increased from a level of $148.1 million in 1980-1989 periods to an average expenditure of $1,135.4 million in 2011-2013 periods. Consequently, real per capita expenditure in agricultural research in Nigeria grew from $1.8 in 1980s to $6.8 in 2011-2013 periods. As a percentage of agriculture GDP, the level of funding for agricultural research rose from 0.2% to 0.9% between 1980 and 2013 (see Table 14).

The increase in intensity of fertilizer use, chemical weeds control and pesticides applications by Nigeria paddy rice farm households were also responsible for the expansion in paddy rice output as recorded between 1960 and 2013(Kijima, Otsuka, & Sserunkuuma, 2011). Table 17 showed the trend in consumption of fertilizer in Nigeria, which indicated that fertilizer consumption increased by an average of 28.0% and 35.5% per annum in 1960s and 1970s, respectively. In particular, average annual consumption of fertilizer increased substantially to 252, 900 and 285,200 metric tons in 1980s and 1990s, respectively. Thus, the available evidence from the analysis showed that the increase in fertilizer consumption by Nigeria farmers can be attributed to improvements in fertilizer procurement by the Federal Government, improved distribution system, and implementation of fertilizer subsidy policy by all tiers of government (Nmadu & Amos, 2009).

Constraints on Paddy Rice Production in Nigeria

Despite efficiency gains and higher output achieved in the last five decades, the rice subsector in Nigeria is still facing major constraints. These constraints generally, had impinged on technical and economic efficiencies levels of paddy rice farm households, leading to rising annual supply-demand deficit that was filled by importation of rice. Nin-Pratt et al. (2010) identified a list of economic and environmental constraints, which are inhibiting greater performances of paddy rice farm households in Nigeria. These constraints were inappropriate use of inputs such as improved and hybrid seed varieties, inadequate application of fertilizers and other chemical weeds control, poor extension services, impact of market failures, failure of extension services, frequent floods and droughts and poor credit delivery to paddy rice farmers.

Majority of rural paddy rice farm households in Nigeria are reluctant to formally adopt new improved rice seed varieties (Takeshima, 2014, 2011). These traditional species of rice seeds planted have low yields in terms of paddy rice output per hectare. The poor reception is attributed to socioeconomic characteristics of rural rice farm households. Ojo, Bawa and Chuffor (2013) opined that peculiar socioeconomic characteristics of farm households help to shape perceptions and attitudes towards modernization in agricultural production in general, and rice production in particular. The rice production landscape in Nigeria is also characterized by small-scale and poor resource-based farmers. These farmers lack financial and educational capacities to acquire and understand new technologies and use new rice seed varieties. Thus, the use of traditional low quality rice seeds remained an obstacle that had hindered improvement in rice production efficiency by paddy rice farmers in Nigeria (Afolami et al., 2012).

Despite the increase in fertilizer consumption by the country, it is equally inadequate. Low applications of fertilizer and other farm chemicals had affected the capacities of paddy rice farmers to achieve higher efficiency and output. Tillman et al. (2002) poised that ‘’agricultural practices determine the level of food production and to a great extent, the state of global environment – in some regions of the world, crop production is hindered by too little application of fertilizers’’(p. 671). Therefore, intensification of rice production means intensity in application of fertilizers and the use of other weed and pest chemicals. The major obstacles to higher application of fertilizer were: inefficient and long fertilizer supply chain, inadequate domestic supply, high exchange rate affecting final cost farmers pay on fertilizer and ignorance (Fuentes, Bumb, & Johnson, 2012).

Market failure is equally an impediment towards improving rice production and cost efficiencies and higher output in Nigeria. A market failure is defined as the situation where free markets failed to allocate resources efficiently leading to price volatility. A successful paddy rice market should be characterized by a stable market price, which provides remarkable incentives for higher producers' efficiency, yields and output. An evaluation of paddy and locally milled rice markets in Nigeria showed an unstable paddy and locally milled rice market prices in the past five decades.

Table 15

Market Prices of Local Rice in Nigeria (November 2009 = 100)

Year	Paddy Rice Real farm gate Price (Naira)	Annual Changes %	Milled Rice Real Retail Price (Naira)	Annual Changes %	Share of Paddy Rice in Milled Rice Price (%)
1995	78,134.9	(34.7)	185,067.0	(12.4)	42.2
2000	137,870.4	60.5	238,240.1	7.1	57.9
2005	165,271.9	2.3	220,824.6	(7.6)	74.8
2006	146,424.9	11.5	255,684.4	(1.8)	57.3
2007	113,442.3	(27.3)	257,646.1	0.3	44.0
2008	131,598.1	7.6	239,944.4	5.5	54.8
2009	65,125.4	34.3	219,093.9	(3.4)	29.7
2010	59,861.4	(11.4)	213,934.1	15.8	28.0
2011	59,359.1	(22.5)	211,996.9	0.8	28.0
2012	65,347.4	16.0	130,694.9	(6.9)	50.0
2013	62,905.0	(50.5)	125,810.0	(8.7)	50.0
Average	108,065.9	0.1	212,042.3	0.6	50.7

Notes. Data sourced from International Rice Research Institute [IRRI] Database. Retrieved from http://ricestat.irri.org:8080/wrs2/entrypoint.htm and Central Bank of Nigeria Annual Report and Statement of Accounts. All prices are converted in real terms in current 2013 prices.

Therefore, price volatility is described as variations in commodity price in local markets over time and these volatilities create uncertainties and they do have negative impact on production and cost decisions and efficiencies (Huchet-Bourdon, 2011). Uncertainty creates fear and may result in less than optimal production and investment decisions. Table 15 showed the trend in prices of local paddy and milled rice produced in Nigeria.

Thus, farm gate price for paddy rice is described as a price in the rice value chain and therefore, represents the price that is paid to rice farmers by brokers, aggregators, wholesalers, and speculators. Simply, it provides adequate signal and information about cost of rice production. The farm gate price like any other prices is determined by the interplay of supply and demand. However, in most countries, interventions by governments using policy of guaranteed minimum commodity price to protect producers is a common feature of the local paddy rice markets (International Monetary Fund [IMF], 2004).

The trend in real prices for paddy and locally milled rice in local markets were unstable between 1995 and 2013. In other words, the long-run increase in real prices for paddy rice in local markets in Nigeria stood at an average of 0.1%, while that of locally milled rice also was an average of 0.6% during the same period. A common feature of rice market was low premium that paddy rice farmers get on their outputs. The long-run share of farm gate price of paddy rice to price of locally milled rice was 50.7%. Given the cost of production, the remuneration of paddy rice farm households is described as unsatisfactory (Sahel & West Africa Club Secretariat (SWAC), 2011).

Lack of access to agricultural information and extension services is also described as another hindrance to paddy rice production in Nigeria (Nwankwo, 2010). Since, majority of rice farmers are illiterates or semi literates, access to information on production technologies, markets and other transaction costs, which are vital for improving rice producers' efficiency levels is limited. Thus, access to agricultural extension services is described as a necessary condition to enhancing producers' efficiency and output. According to Agbebi, (2012), ''agricultural extension is a discipline, which seeks to develop professional competencies essential to operation of a system of services that assist rural people, through educational programs for improved farming methods and techniques, increased production efficiency and income, level of living and achievement of a more fulfilling rural life'' (p.62). Thus, agricultural extension agents have the responsibilities of educating and disseminating useful and timely agricultural information to the farmers.

A fundamental problem to rice production in Nigeria is the rising risk posed by changing climatic conditions in the country. Rice cultivation requires a lot of water for higher productivity performance as such insufficient rainfall is a major risk on production decisions. Zgajnar and Kavcic (2011) argued that uncertainty caused primarily by natural hazards pose risks to peasant farmers' production decisions. The climatic challenges are frequent droughts experienced in the northern part and flooding of rice fields in the southern and middle belt areas of the country. Droughts in the northern Nigeria are attributed to shortness of rainfall, while the floods in the south and middle belts are also caused by heavy rainfall, thereby making the major rivers to overflow their banks. These climatic conditions are major impediments to rice production investment (Bariweni, Tawari, & Abowei, 2012). Kolawole, Olayemi, and Ajayi (2011) poised that regular occurrence of floods and droughts in Nigeria are results of climate change and the impact of global warming.

Lack of access and poor credit delivery to rice farmers were equally identified as affecting farm productive efficiency and productivity growth. Obansa and Maduekwe (2013) argued that finance is the sole of any business and therefore, agricultural financing represents a long-term financing (that is, medium to long term capital), which aims at inducing agriculture-led growth and improving farm productive efficiency. In this regard, agricultural credit plays an important role in increasing agricultural efficiency and productivity. For example, access and timely advancement of credit enable rice farmers to purchase required inputs for carrying out farming activities on time (Omobolanle, 2010). For instance, average annual growth rate of real credit to agricultural sector was 13.5% from 1960 to 2013. It accounted for an average share of 9.0% of real total loans to the economy (CBN, Statistical Bulletin, 2013).

Supply-Demand Gap Analysis

This section reviewed Nigeria's rice supply-demand gap, identifying the dynamics in the rice value chain and the persistent declining self-sufficiency. Thus, the section xrays the problems of the subsector. Rice self-sufficiency is defined as a ratio of local rice consumption to local milled rice production (Peljor & Minot, 2010). Table 16 replicates a scenario that showed rising trend in milled rice supply deficit in Nigeria, from 1,100 metric tons in 1960s to 2.4 million metric tons in 2013. Between 1960 and 2013, Nigeria has persistently imported foreign milled rice to augment local supply deficit. This was an average of 2.3 million metric tons of imported rice per annum. Self-sufficiency ratio has also declined from 99.6% in 1960s to 55.3% in 2013. The long-run self-sufficiency ratio of the rice value chain between 1960 and 2013 stood at 55.1%. The balance of 44.9% during this period was imported to meet local demand for rice. Thus, despite recorded increase in international price of rice, the country in the past five decades has experienced rice import surges between 1970 and 2013.

Table 16

Selected Indicators of Rice Supply-Demand Dynamics in Nigeria

Years	Production Paddy Rice	Local Milled Rice	Consumption Milled Rice	Supply Gap	Sufficiency Rate (%)	Imports %
1960-1969	369.6	245.7	246.8	-1.1	99.6	0.4
1970-1979	536.0	356.5	505.6	-149.1	70.5	29.5
1980-1989	1355.0	866.1	1262.5	-396.4	68.6	31.4
1990-1999	3029.9	1817.9	2432.5	-614.6	74.7	25.3
2000-2010	3558.7	2194.9	3848.8	-1653.9	57.0	43.0
2011	4300.0	2709.0	4921.0	-2212.0	55.0	45.0
2012	4524.0	2850.0	5175.0	-2325.0	55.1	44.9
2013	4529.2	2998.2	5423.0	-2424.8	55.3	44.7
2011-2013	4451.1	2852.4	5173.0	-2320.6	55.1	44.9

Notes. Data sourced from International Rice Research Institute [IRRI] Database. Retrieved from http://ricestat.irri.org:8080/wrs2/entrypoint.htm and Central Bank of Nigeria Annual Report and Statement of Accounts. Data are in thousand metric tons otherwise as indicated, and 2013 data are author's estimates.

Available data explained that rice importation in terms of volume and value into Nigeria has constantly increased since 1970. However, these changes have been erratic depending on the different trade regimes and tariff structure in each year. These changes have been described as import surges (see Table 16). de Nigris (2005) argued that an import surge has the following characteristics: an increase in volume of import relative to local production, import of the commodity is a threat to local production, the increase is a recent phenomenon, sudden, sharp and significant enough in quantity and quality and the import is large enough to cause a major distress or serious injury to the local industries.

Table 17
Selected Indicators of International Trade on Rice by Nigeria

Average Indicators	1960-1969	1970-1979	1980-1989	1990-1999	2000-2010	2011-2013	1960-2013
Volume of Rice Imports (000, m/tons)	1.1	199.4	528.9	589.9	1799.1	2986.4	778.7
Annual Changes in Volume (%)	5.6	256.3	2.5	23.2	4.2	6.2	55.2
Value of Rice Imports (Million U.S. $)	0.2	108.6	156.2	151.5	583.4	1,868.9	295.1
Annual Changes in Value (%)	20.2	406.4	-7.4	18.2	22.0	10.9	86.4
Value of Food Imports (Million U.S. $)	65.8	749.9	1,593.8	713.9	3,586.5	5,570.0	1573.5
Share of Value of Rice Imports (%)	0.4	8.7	12.2	21.8	16.2	33.6	13.4
Export Prices (U.S$ m/t, FOB)	230.1	493.4	440.7	306.3	383.0	632.6	389.9
Annual Changes in Export prices (%)	6.1	21.1	-5.0	-1.5	11.3	4.7	6.0

Notes: Data sourced from International Rice Research Institute [IRRI] Database: Retrieved from http://ricestat.irri.org:8080/wrs2/entrypoint.htm and United Nations Commodity Trade Database: Retrieved from http://comtrade.un.org/db/dq

Grethe and Nolte (2005) also defined import surge to mean a situation in which the volume or value is sudden, significant and is in excess of a normal level. Thus, available statistics on volume and value of rice imports by Nigeria indicated that Nigeria experienced rice import surges in 1970s, 2000-2010 and between 2011 and 2013 periods. Thus, these import surges were the major source of concern to the Federal Government, thus justifying the specific interventions and initiatives to reduce dependence on foreign rice import by increasing locally produced paddy and milled rice.

Thus, the volume and value of rice import by Nigeria has increased since 1970s. For instance, the volume and value of rice import rose from averages of 199,400.0 metric tons and U.S$108.6 million per annum in 1970s to averages of 3.0 million metric tons and U.S$1,868.9 million per annum in 2011-2013 periods. Between 1960 and 2013, both volume and value of rice imports increased by 55.2% and 86.4%, respectively. Its share in total food imports (includes food and live animals, beverages and tobacco, oils seeds, oil nuts and oil kernels) increased speedily to a level of 33.6% in 2011-2013 periods (see Table 17).

A special examination showed that the growing rice import into Nigeria is influenced by factors other than export price of rice. For example, in 1970s, rice import by volume increased when export price was highest at U.S$493.4 for a metric ton. Similarly in 2000-2010 and 2011-2013 periods when export price of the commodity increased by 11.3% and 4.7%, the volume of imports also increased sharply by 4.2% and 6.2%, respectively.

Table 18
Distribution of Sources of Rice Imports to Nigeria (2009-2013)

	In Percent				
Regions/Continents	2009	2010	2011	2012	2009-2012
Asia	8.0	6.0	12.5	57.6	21.0
Americas	68.0	84.8	84.5	42.1	69.9
Middle East	12.0	4.0	2.3	0.1	4.6
Europe	11.4	2.6	0.0	0.0	3.5
Africa	0.7	2.6	0.7	0.0	1.0
Oceania	0.0	0.0	0.0	0.1	0.0
Total	100.0	100.0	100.0	100.0	100.0

Note. Data compiled from Comtrade Database, United Nations Trade Statistics Division.

Therefore, the increasing rice import is attributed to four economic reasons. First, the importation of rice is dictated by the instability in domestic supply of rice, due to production and cost inefficiencies along the rice value chain. Second are unilateral and frequent changes in Federal Government rice trade policies either due to external pressures or by internal pressures from different interest groups. These actions lower the competitiveness of local producers compared to their counterparts elsewhere. Third are the frequent changes in agricultural financing policy as there are frequent changes in inputs subsidy policies. These frequent changes produce disincentive to higher production by the local rice farmers. Finally is the lingering issue of quality of local milled rice compared to imported rice (Abayomi et al., 2010).

Rice imports into Nigeria came from diversified sources of which America continent export on the average was about 69.9% per annum (see Table 18). The most significant source of rice import from the America continent to Nigeria was Brazil. Rice import from Brazil accounted for an average of 68.1% of total rice import between 2009 and 2012. The level of rice import from Asian continent stood at an average of 21.0% per annum. However, rice trade between the Asian countries and Nigeria had witnessed substantial increase in recent years, rising from 8.0% in 2009 to 57.6% in 2012. The main trading partners from Asian continent were: India (13.7%), Thailand (2.8%) and China (1.4%).

Overview of Nigeria's Rice Sub-Sector Policies

Agricultural policies in Nigeria have evolved since independence in 1960. In 1998, after years of neglect, the Federal Government launched an agricultural policy with a sole objective of ensuring food security for the country and specifically, to improve the production of cereals. Among the cereals, rice was a major target and the policy was aimed at improving producers' efficiency, raising local rice output and reversing rice importation. However, following implementation difficulties, the Federal Government in 2011, reformulated a new agricultural policy called the Agricultural Transformation Agenda. The overall objectives of the new agenda include: self-sufficiency in basic food supply and the attainment of food security, increased production of agricultural raw materials for industries, increased production, and processing of export crops and generating gainful employment (Federal Ministry of Agriculture and Rural Development, [FMARD] 2011).

Following the Agricultural Transformation Agenda, the Federal Government has developed the new rice subsector policy/program. The new policy has the following objectives: an appropriate increase in national output of rice, curbing the level of importation of rice from other countries, reducing amount of scarce foreign exchange devoted to rice importation, creating employment and enhancing rice farm households' incomes; and developing and diversifying the export base of the country.

In the circumstance of the new policy, in 2013 the Federal Government re-launched the Presidential Initiative on Rice. Globally, common strategies used to implement rice subsector policy are: - rice commodity pricing policy, rice trade policies (import quotas, export quotas, tariffs, direct export and import bans, etc), and rice input subsidy policy (seed, fertilizer and chemicals), credit policy, extension services policy and public investment in rice production (Anderson, 2010).

In Nigeria, the achievements of rice subsector objectives are targeted with the following strategies: rice trade policy, inputs subsidy policy, and policies on access to: credit, land and extension services. In addition, the Federal Government and sub national governments have also put in place paddy rice minimum guarantee price policy and have also used public investment in irrigation, agricultural machineries, fertilizer production and agricultural education on the rice subsector to induce higher producers' efficiency and local output in the subsector (FMARD, 2011).

For instance, the re-launched Presidential Initiative on rice has the following strategic themes: introduction of 100% duty levy on imported polished rice; distribution of R-boxes to rice farmers; introduction of 50% duty rebate on imported brown rice; attraction of donor-supported initiatives, implementation of an outright ban on rice importation by 2015 and encouragement of large-scale rice milling investors both foreign and local. Thus, the rest of this section discusses the relevant policies explained above and employed by the Federal Government to promote rice subsector productive efficiency and by extension local rice output.

Rice Trade Policy

Federal Government used trade policy (import quota, tariffs, import restrictions and import bans) to regulate international trade in rice so as to protect local producers in Nigeria (Miranda, Kume, & Piani, 2010). The use of rice trade policies in regulating rice import dates back to 1970s. Emodi and Madukwe (2008) categorized the national rice trade policy into three distinct periods namely; pre-ban period (1971-1985), ban period (1985-1994), and post-ban period (1996-to-date). These actions were largely dictated by internal and external environments, which were inclusive of world supplies, prices of rice at both domestic and international markets and the multiplicity of interest groups.

The pre-ban period covered 1971 to 1985 and is broadly divided into pre-crisis period (1971- 1978) and crisis period (1979-1985). The pre-crisis period was a period of implementation of trade liberalization and the use of moderate import tariffs in the spirit of world trade. Thus, between 1971 and 1978 rice import tariff ranged from 10% to 20% except in 1974 when the tariff was 66.6% (see Table 19). From 1979, Nigeria began to experience balance of payment problems, resulting in a rapid depletion of foreign reserves. This subsequently induced crisis within the economy. Therefore, to strengthen the economy, trade liberalization was re-appraised and the Federal Government re-introduced drastic measures to curtail rice import.

Table 19

Chronology of Nigeria Rice Trade Policies

Period	Policy Measures
Pre Ban Period	
Prior to April 1974	66.6% Tariff
April 1974-April 1975	20% Tariff
April 1977 - April 1978	10% Tariff
April 1978-June 1978	20% Tariff
June 1978-October 1978	19% Tariff
October 1978-April 1979	Imports in containers under 50kg were banned
April 1979	Imports placed on restricted license only for Govt. Agencies
September 1979	6-month ban on all rice imports
January 1980	Import license issued for only 200,000 metric tons of rice only
October 1980	Rice under import restrictions with no quantitative restrictions
December 1980	Presidential Task Force (PTF) on rice was created and issued allocations to customers and traders through Nigeria National Supply Company (NNSC)
May 1982	PTF began the issue of allocations directly to customers and traders in addition to those issued by NNSC
January 1984	PTF Disbanded and rice importation placed under general license
Ban Period	
October 1985 to 1994	Importation of rice banned as Structural Adjustment Program was introduced and all commodity boards were disbanded
Post Ban Period	
1995	100% Tariff
1996-2000	50% Tariff
2001	85% Tariff
2002	100% Tariff.
2003	150% Tariff
2004	75% Tariff
2005-2006	100% Tariff
2007	109% Tariff
2008	0-30% Tariff - This was 0% Jan - Sept, and 30% by Oct.
2009	30% Tariff
2010	30% Tariff
2011-2012	50% Tariff
2013	110% Tariff
2014	110% Tariff

Notes: Compiled from UNEP (2005), Nigeria Tax Data Card, 2013 and Federal Government Budgets of Nigeria for various years

Sequel to this, in 1979 import quota and quantitative restrictions became the major instruments. However, the implementation of these tools came with the introduction of rice import license policy. The process was massively abused, thus leading to rent seeking activities by various interest groups. These trade policy instruments were not effective as anticipated. As a result, in 1986 following the introduction of Structural Adjustment Program (SAP), Federal Government imposed an outright ban on rice import, which lasted till December, 1994. One major outcome of this ban was the emergence of illegal trade on rice imports through the land borders of Nigeria with the neighbors thereby, dampening the achievement of the intentions of the ban policy. Due to pressures from various actors, the outright ban was jettisoned in 1995. The instrument used so far, was imposition of heavy import duty although the annual imposed tariffs had never been consistent but generally erratic. The tariff ranged from 50% in 1996 - 2000 and 2010 - 2012 periods to 150% in 2003.

Inputs Subsidy Policy

Another policy instrument used by the Federal Government to support paddy rice production was inputs subsidy policies. Subsidies on farm inputs by government are aimed at reducing production cost and increasing farm profit margins. Generally, they are intended to serve as incentives to farmers to raise their technical and economic efficiencies levels and rice farm outputs. For example, Federal Government grants inputs subsidies for fertilizer, herbicides, pesticides and rice seeds. Banful, Nkonya and Oboh (2009) explained the rationale behind Federal Government of Nigeria (FGN) implementation of national fertilizer subsidy. This was in recognition of the role of fertilizer usage in intensification of rice cultivation and possible impact on farm production and cost efficiencies. Therefore, in 1976, Federal Government of Nigeria expanded its responsibility for intensification of agricultural production and rice production in particular, by taking over the procurement, production, marketing and distribution of fertilizer to farmers.

Broad objective of national policy on fertilizer was to ensure Nigeria's farmers obtain fertilizer as a major input for agricultural production in time, adequately and at affordable prices. Under the fertilizer pricing policy, Federal Government implemented subsidies at different levels and at different time periods. The levels of fertilizer subsidy however, varied from year to year, depending on annual revenue positions of governments. The initial take-off subsidy rate was about 95.0% of the actual price. However, over the years, fertilizer subsidy has declined, while sub national governments have also assumed some additional responsibilities in the fertilizer market (Liverpool-Tasie & Takeshima, 2013).

Rice seed subsidy policy was another input subsidy put in place by the Federal Government. The rice seed subsidy is been implemented using R-Boxes. Each R-Box contains improved rice seeds and other relevant chemical inputs, which are distributed to rice farmers at subsidized rates. The policy stresses the importance of high yielding rice seeds at affordable prices to rice farmers (Adetumbi, Saka, & Fato, 2010). The government is also implementing varietal developments and improvements, which are aimed at improving productive efficiency of rice farming households and higher output (Takeshima, Oyekale, Olatokun &Salau, 2010).

Public Investment in Agriculture

Federal Government has also used fiscal policy instruments of taxation and government expenditure to support agriculture and rice production, specifically. These fiscal instruments are tax incentives to paddy rice producers and rice millers and public expenditure on agricultural facilities. The investment involved direct expenditure for the provision of agricultural facilities, using various agencies established for the purpose.

Table 20

Federal Government Expenditure on Agricultural Sector

Yearly Averages	Total Agriculture Expenditure at 2010 Prices(US$M)	Agric. Expenditure Per Capita at 2010 Prices(US$)	Agric. Recurrent Expenditure at 2010 Prices(US$M)	Agric. Investment Expenditure at 2010 Prices(US$M)	Agriculture Exp as % of Total Expenditure	Agriculture Exp as % of GDP
1970-1979	267.6	4.0	49.5	218.1	2.2	0.4
1980-1989	236.3	3.0	28.4	207.9	2.8	0.4
1990-1999	10.2	0.1	2.1	8.1	1.9	0.2
2000-2010	7.5	0.1	1.8	5.7	3.9	0.3
2011	6.1	0.0	2.4	3.7	2.2	0.2
2012	5.2	0.0	1.8	3.4	2.1	0.1
2013	5.2	0.0	1.7	3.5	2.2	0.1
1970-2013	119.1	1.6	18.8	100.4	2.7	0.3

Notes: Data compiled from the CBN Annual Reports from 1970-2013. US$M refers to million. The real values were converted using the 2010 prices. Data for 2013 are estimates.

Table 20 presents public spending on agriculture by Federal Government between 1970 and 2013. In real dollar terms, public spending on agriculture between 1970 and 2013 stood at an average of U.S$119.1 million per annum. This accounted for an average of 2.7% of total real expenditure of the Federal Government or an average of 0.3% of GDP.

Credit Policy

Nosiru (2010) explained that micro credit to rice farmers is an essential support to the subsector because it enables farmers to buy farm inputs they need on time. Thus, he identified four main purposes why credit policy by governments to rice farmers is relevant. These are: improving accessibility of credit, increasing the volume of funds available for lending to farmers, encouraging timely lending to farmers and ensuring that the cost of credit is low. Special interests on agricultural lending to farmers are justified by the fact that this group generally has low and poor resource base, and lack the necessary collateral required by commercial banks.

Thus, the Federal Government of Nigeria initiated the development of agricultural credit markets, including the establishment of a specialized agricultural bank, establishment of ACGSF and micro finance scheme. The ACGSF is aimed at providing credit covers to commercial banks lending to agricultural sector. The scheme was intended to increase access to credit to farmers and is jointly sponsored by Federal Government and Central Bank of Nigeria. The loan extended to farmers by lending institutions has a guarantee cover of up to 75% of the loan amount in cases of defaults.

Land Policy

Land remains a primary source of wealth and its relevance to agricultural production is established in the literature (Aniagboso & Iwuchukwu, 2011). Major objective of any land policy for agriculture is to make land available to intending farmers and at an affordable price. Ownership of agricultural land in Nigeria is based on communal land ownership. Prior to the promulgation of the Land Use Act in 1978, communal land ownership is vested on the traditional councils, and the mode varies from one community to another. The land use policy is implemented through Land Use Act of 1978. This is aimed at removing bottlenecks on land ownership. Hence the Act vested authority on land to the State Governors and the Chairmen of various local councils. As a policy, governments are now found engaged in acquisition of agricultural land and making it accessible to farmers for production.

Paddy Rice Minimum Guarantee Price

Agricultural commodity marketing and pricing is described as on-farm and off-farm activities and they involve commercialization of agricultural produce. They include: post-harvest handling, processing, marketing and other related commercial activities. Rice commodity pricing are aimed at reducing price risks for producers, fending out pressures when prices fall, thereby avoiding adjustment costs for rice producers. The overall objective of the policy is farm gate price stabilization in the local market (World Trade Organization [WTO], 2010). Within the new rice policy framework, the Federal Government established National Food Reserve Agency, which is charged with the responsibility of warehousing surplus paddy rice and other grains. Thus, the government provides funds for the construction of grain storage and reserve centers throughout the states and agro-zones. With this policy, the Federal Government of Nigeria has assumed buyer of last resort and it is intended to control prices of paddy rice and ensuring farmers have access to adequate revenue.

Farm Extension Service Policy

Policy on extension services takes different forms including: availability of occasional assistance by specialists, formal trainings on specific topics for groups of rice farmers and specialists working directly with rice farmers (Cerdán-Infantes, Maffioli, & Ubfal, 2008). To improve rice production some form of modern technologies, seed varieties and knowledge of markets are needed by farmers. One responsibility of the extension workers is to transfer knowledge to the rice farmers. As a consequence, the Federal Government realizing these responsibilities developed a nation-wide agricultural extension service system through the National Policy on Extension Services.

Theoretical Framework

Preliminaries on the Theory of Production

Practical applications of efficiency measurements have relied upon the parsimonious specifications of the type of production technology associated with producers. In other words, production technologies are used to represent relationships between inputs and output(s). Following Coelli, O'Donnell and Battese (2005), it is assumed that producers are using nonnegative vector of inputs denoted by $x = (x_1, x_2.....,x_N) \in R_+^N$ to produce nonnegative vector of outputs denoted by $y = (y_1, y_2.....,y_M) \in R_+^{M}$. The technology set ($T$) for a producer therefore, can be defined as:

$$T \equiv \{(x, y): x \text{ can produce } y\} \quad (5)$$

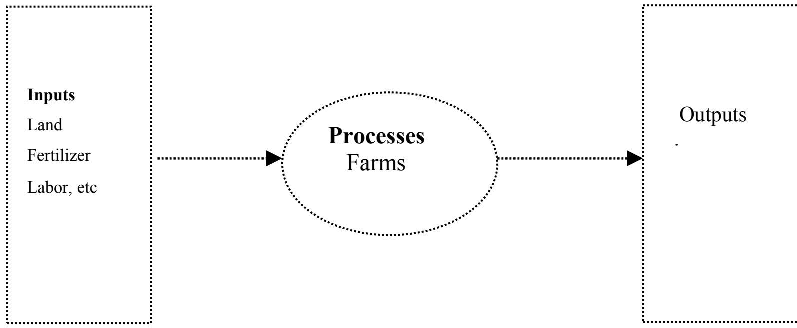

Figure 1. A diagram showing the production box
Adapted from '' Technical efficiency of public district hospitals and health centers in Ghana: A pilot study ''by Osei, D., d'Almedia, S., George, M. O., Kirigia, J. M., Mensah, A. O., Kainyu, L. H., 2005, *Biomed Central.*p.3.

Figure 1 depicts the formal relationship between farm inputs and outputs. Farmers operate within a production box, representing the technology process of input transformation. However, for efficient production process, the increase in bundle of inputs must be less than the maximum output produced from the inputs. This technology set comprises pairs (x, y) as x can produce y or y is producible from x. Producers' production technology represents production possibility set, showing the technical relationships between inputs and outputs, which could be expressed in functional form. Hence producers' production function is an expression, which maps available production technology from inputs space into single-output or multiple-outputs space.

The *T* therefore approximates maximal value of output(s) that can be produced from each bundle of inputs. The input space or input requirement set is given as L(y), representing a vector of all inputs required to produce maximum output (s). Thus, input space depicts the input-input technical relationship that the producer is using to produce a vector of output (s) and is defined as:

$$L(y) \equiv \{x: x \text{ can produce } y\} = \{x: (x, y) \in T\} \qquad (6)$$

The input space is therefore a compact set that is unique to the output produced and its minimum exists for the intended output produced. Formally the output space or output set P(x) also represents the set of desirable vector of output(s) that are producible from an input vector x. Accordingly the output space describes output-output technical relationship in a multiple output space, and is written as:

$$P(x) \equiv \{y: x \text{ can produce } y\} = \{y: (x, y) \in T\} \qquad (7)$$

These production technologies are assumed to satisfy the following properties:

Closed and nonempty properties. The production technology is assumed to be closed and nonempty, meaning that $y \geq 0$. The closed assumption also means that it contains its own boundary, which assures technical efficient input and output vectors. It also implies there is an optimal solution to producer profit maximization objective. The nonempty property of production technology explains the possibility of producing any positive output.

No free lunch. This shows that the production technology is essentially weak as such it is not possible to produce any output without using inputs. Simply, output cannot take positive values without application of at least one input. Thus, the production technology set is defined as:

$T: (x, 0) \in T$ and $(0, y) \in T$ then $y = 0$ (8)

Monotonicity. This states that additional unit of an input will not in any way decrease output as such If $x^0 \geq x^1$; then $f(x^0) \geq f(x^1)$. Put simply, the assumption ensures that the marginal products of inputs are always positive and as such guarantees the radial expansion and contraction of feasible inputs and outputs.

Free disposal. This is interpreted as the ability of producers to do away with inputs or outputs, if they wish and the technology set satisfies the condition:

$(x, y) \in T$ and $x' \geq x$, $y' \leq y$; then also $(x'\ y) \in T$ or $(x, y') \in T$ (9)

Thus, given vector of inputs x, it is possible to decrease production of any output by any desired quantity by eliminating any excess output free of charge. In a similar analogy, it is possible to produce a given output y with more input resources than is totally required. Moreover, free disposability can be seen as a first- order curvature condition for production efficient frontier. For instance, the maximum output will not decrease if input usage increases, meaning that the marginal product of every input is non-negative

Convexity. The convexity property means that if $y, y' \in T$ and $\alpha \in [0, 1]$, then $\alpha y + (1-\alpha) y' \in T$. Alternatively, the convexity can be seen as the second-order condition, implying that the maximum output increases at non-increasing rate as inputs increase. This is interpreted to mean that the marginal product is non- increasing. In microeconomics this is known as law of diminishing marginal productivity (Kumbhakar & Lovell, 2003).

Economics of Efficiency Measures

The general application of the production theory is its usefulness in evaluating the performances of producing units in terms of producers' efficiency levels in the production of a product or multiple products. Specifically, efficiency measurement in agricultural production has generated interests in recent years, following the pioneer work by Farrell (1957). Formally, farm's efficiency performance is a measure expressed as a ratio between potential output, minimum cost, and maximum revenue and/or profit and the observed output, cost, and revenue and/or profit attained by a producer. Thus, the ratio is bounded within an interval of zero and one (Watkins et al., 2014).

Farrell (1957) assumed that each producing unit is an independent decision-making unit (DMUs). So the efficiency of each DMU is derived relative to other DMUs and the *best practice* DMU. However, in production literature, estimations of production efficiency frontiers of DMUs use three types of measures. These measures are: technical, allocative and economic efficiencies. Technical efficiency (TE) measure refers to the ability of a DMU to produce maximum possible output from a given minimum bundle of inputs. If a farm is technically efficient, it means that the farm is not in any way over utilizing any available inputs (Gabdo et al., 2014).

Similarly, allocative efficiency (AE) is the ability of a technically efficient DMU to use inputs in proportion that minimizes production costs given the relative input prices or maximizes revenue and profit, given the relative input and output prices. Allocative efficiency is therefore described as a ratio of minimum costs which is required by a DMU to produce given level of outputs and the actual total costs incurred by the DMU adjusted for technical efficiency. It could also be defined as a ratio of potential maximum revenue or profit attainable from output produced and the observed revenue or profit, also adjusted for technical efficiency.

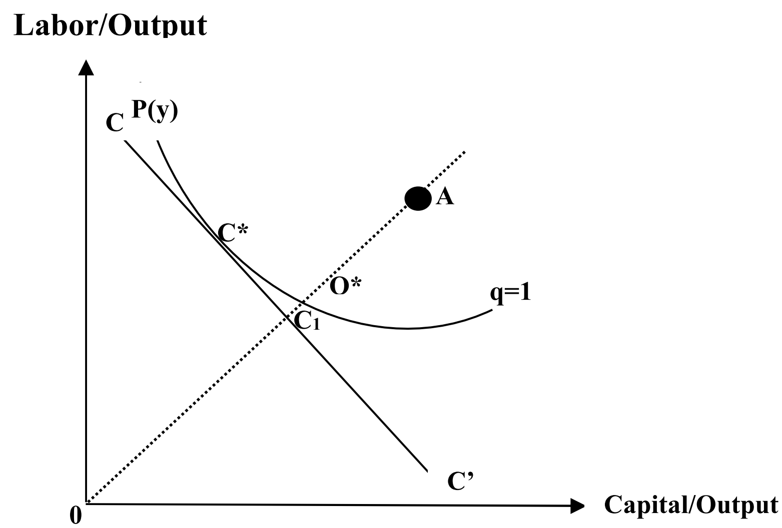

Figure 2. A graph showing the technical and allocative efficiency. Adapted from ''. A practitioner's guide to Stochastic Frontier Analysis using STATA'' by Kumbhakar, S. C., Wang, Hung-Jen, & Horncastle, A. P., 2015, Cambridge University Press: New York, NY, p. 39.

Thus, a DMU can be allocatively efficient (price efficient) when the marginal revenue attained from an additional unit of production is equal to the marginal cost of inputs (MR=MC). Allocative inefficiency explicitly means that the paddy rice farms are utilizing farm inputs in wrong proportions, given the relative factor prices (Oluyole et al., 2013).

Färe et al. (1994) stated that farm production technology describes all possible transformations of input vector (x_t) into output vector (y_t) in a given year t. Therefore, I assumed that the production technology produces a single output (y) with two inputs (labor and capital) as illustrated in Figure 2. The input possibility set is represented in the graphical presentation showing all possible combinations of labor and capital to produce for example, a unit of rice output. Thus, the isoquant line presents the production possibility frontier for a producer and is given as q = 1. This input vector cannot be reduced without leaving the production possibility set however, the levels of individual inputs can vary along the isoquant line.

Hence the technical efficiency of producing unit A is TE = 0Q*/0A. The point Q* means a technically efficient output because it lies on the efficient isoquant and provides the possibility of expanding production results precisely from the distance between production unit A, and the frontier along a ray through the origin. The ratio takes the value of between zero and one, indicating the degree of technical efficiency of farms. A rice farmer who has a ratio of one is described as fully technical efficient, and a farmer with a score of zero is fully technical inefficient.

Similarly, since the capital and labor factor prices are known, the slope of isocost line c–c' is constructed. This represents the different combinations of cost of labor and capital for producing different levels of output thus, attaining the least cost of production. The allocative efficiency of a producer operating at A is equally defined as a ratio AE = $0C_1/0Q^*$. Therefore, allocative efficient ratio is similarly bounded by zero and one and the same analogy as in the technical efficiency applies. The distance Q*- C_1, represents the reduction in production costs that could occur when a farmer is producing at allocatively and technically efficient point C*, instead at the technically efficient but allocatively inefficient point Q*.

Similarly, Figure 2 also explained the concept of economic efficiency measure of producers. Thibbotuwawa, Mugera, and White (2013) defined economic efficiency (EE) as a product of technical and allocative efficiencies, thus it is a ratio depicting the cost, revenue or profit functions of producers. The ratio is given as:

$$EE = 0C_1/0A \qquad (10)$$

The ratio is also bounded between zero and one, while producers that have a ratio of one are described as fully economic efficient and those with zero efficiency ratios are described as fully economic inefficient. Again, the distance of C_1–A, represents cost reduction requirement. The product of TE and AE gives the economic efficiency as shown in equation 10:

$$TE \times AE = 0Q^*/0A \times OC_1/0Q^* = 0C_1/0A = EE \qquad (11)$$

Thus, a DMU is economically efficient if it is both technically and allocatively efficient, while economic efficiency is calculated as a ratio of minimum feasible costs and actual observed costs for a DMU or maximum or potential revenue and/or profit and actual observed revenue and/or profit for a given DMU. These three ratios provide the economic tools with which economists are able to evaluate and make comparisons of producers' performances at a particular time and at different time periods, in a given economy or across different economies.

Relevance of Efficiency Analysis

Producers' efficiency measures and the changes that occur over time is an important policy tool. Its relevance is underscored by the relationship between output expansion, and economic growth and general wellbeing of citizens. Achieving a higher level of efficiency for example, by rice farmers is a necessary condition to achieving higher output and economic growth. Thus, improvements in producers' efficiencies over time are major concerns for agricultural sector policy makers. Dias Avila and Evenson (2010) defined productivity growth as an outcome of technical progress. Technical progress comprises the use of or discovery of a new technology and/or an improvement in an economy's producers' efficiency levels, using the existing domestic technology.

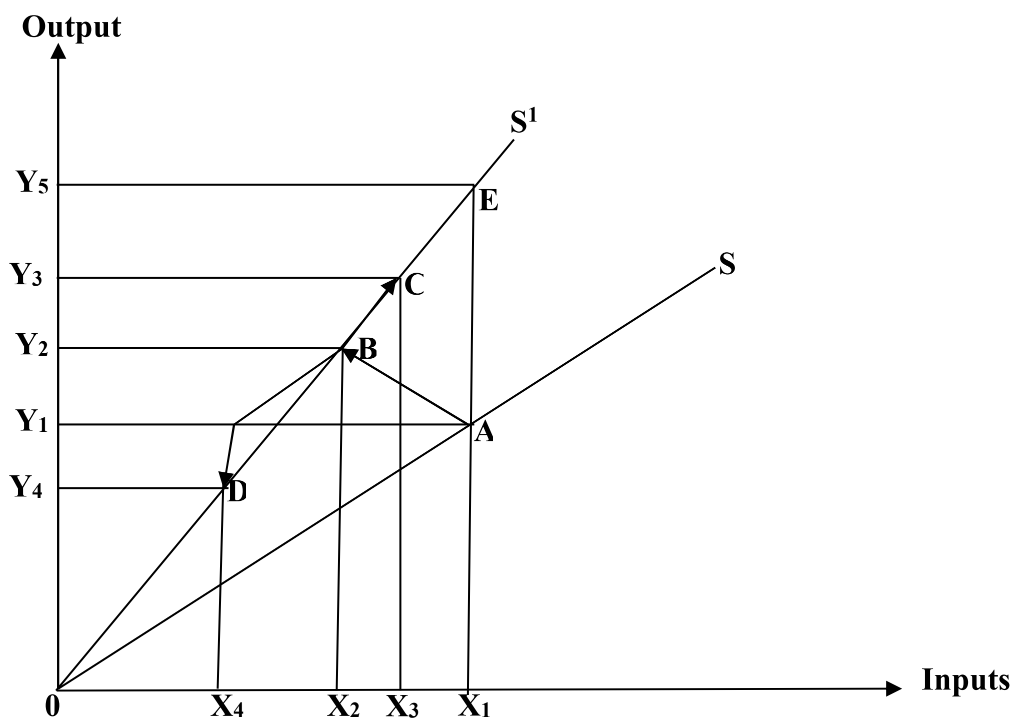

Figure 3. Graph showing the relationship between efficiency gains, output, and economic growth.

Zhang and Whitney (2012) argued that a policy maker has two options for achieving technical progress in any economy. The first strategy means that technical progress could be achieved through development or importation of new technologies. Second is the pursuit of efficiency improvement, using existing domestic technologies. The cost of implementing transfer of new technologies is assumed to be high hence many policy makers in the developing economies prefer to pursue the second option by formulating and implementing policies that could improve producers' efficiency levels with an existing domestic technology.

Improvement in efficiency levels implies that producing units are using less of inputs to produce more output(s). For example, improving efficiency in rice production implies reduction in amount of inputs used by rice farmers. If released inputs are speedily redeployed to other sectors of the economy all things being equal, the overall output of that economy grows and an economic progress is achieved. On the contrary, if the aggregate demand in the economy decelerates because of the inability of economic agents to quickly redeploy excess factors of production released, then the impact of efficiency gain will make no sense.

From this analogy, efficiency gain in production process is positively, related to economic growth. The relationship between efficiency gain, output and economic growth can be formalized using Figure 3. Therefore, it depicts the outcome of improving productive efficiency of producers. When productive efficiency for example, of paddy rice farms increase, then the supply curve for paddy rice shifts upwards from S to S^1. At point B more output Y_2, is produced by employing lesser inputs at X_2. Thus, if the excess labor and capital from paddy rice farms are speedily reemployed in other sectors of the economy, aggregate demand in the economy increases further and farmers move to point C by producing more and employing additional inputs in the paddy rice farms. Thus, agricultural output expands to Y_3, while inputs employed also increase to X_3, reflecting economic growth and higher employment in the economy.

Approaches to Estimating Producers' Efficiency

Measurements of farm production efficiency levels in the literature have employed one or a combination or all of the three dimensions in the empirical literature: - technical, allocative and economic efficiency measures (Coelli, Rahman, & Thirtle, 2002; Watkins et al., 2014). In this study, the three measures were employed to evaluate the impact of Federal Government rice subsector policies on paddy rice producers' efficiency levels using participants from three selected states in Nigeria, during the 2014/2015 cropping season.

This research approach was necessary because estimation of production frontiers with observations of output and inputs only, may not provide answers to the causes of allocative inefficiencies associated with rice farmers even when they are technically efficient. Conversely, an estimation of the combinations of different proportions of inputs given the relative factor prices may not dictate technical inefficiency associated with paddy rice production by the farmers. On this note, the technical efficiency of the paddy rice farms was estimated using the producers' production frontiers, while the economic efficiency of paddy rice farms was estimated employing the producers' cost frontiers. However, the allocative efficiency of the paddy rice farms was derived as a residual from the estimates of technical and economic efficiency scores of the paddy rice farms.

Although empirical assessment of efficiency levels of DMUs has been refined over the years, but two broad approaches have been increasingly applied by researchers: parametric and nonparametric techniques. Among the nonparametric approaches are the DEA estimation procedure, introduced by Charnes, Cooper and Rhodes (1978) and free disposal hull procedure, introduced by Deprins, Simar and Tulkens (1984). Both are not embedded in regression analysis but use linear programming technique to solve for efficiency levels of homogenous producers.

Parametric models however, are embedded in regression estimations, which econometricians are familiar with. Parametric distributions of producers' efficiency scores are either estimated as a deterministic frontier or stochastic frontier. The deterministic frontier generally, attributes all deviations to inefficiencies of producers and uses the OLS, corrected OLS (COLS), and modified OLS (MOLS). Contrastingly, the stochastic frontier estimation partly attributes deviations from the ideal frontier to inefficiencies and other statistical errors in measurement or any other factors beyond the control of the producers.

Nonparametric (DEA) Approach

The DEA approach has become the most popular approach of all the nonparametric approaches applied by researchers in efficiency estimations. The basic features of DEA approach are: it does not impose any specific functional form of the production technology and assumes no specific statistical distribution of error terms. Simply, it assumes that all errors or deviations from the production frontier are attributed to inefficiency of a producer. Therefore, the DEA approach measures and evaluates relative efficiency of peer decision units with multiple inputs and single output or multiple outputs. Thus, it calculates the maximal performance measure for each DMU relative to all other DMUs in a homogenous population. The sole requirement is that each DMU lie on or below the production possibility frontier. The DMUs not found on the frontier are scaled against a convex combination of DMUs on the frontier facet closest to it.

Structure of a DEA model. The structure of a DEA model comprised the type of reference production technology (*T*) available to a producer and the possible category of efficiency measure. The reference technology (*T*) is assumed to be convex and refers to all feasible combinations of inputs and outputs. The second component of the DEA structure is the category of efficiency measure, which is related to the behavioral assumptions of the producers or what is referred to as the producers' production plans as well as the applicable type of efficiency measurement.

Usually, in estimation of producers' efficiency scores, researchers assume that the reference technologies of DMUs have the following characteristics: strong and free disposability of the inputs and outputs, and that all inputs and outputs can be categorized as either discretionary or nondiscretionary, and could also be defined as either categorical or continuous. Thus, the discretionary DEA models classify all inputs and outputs as discretionary, meaning that they are within the control of management. In this regard, management has discretion to alter these inputs and outputs.

Banker and Morey (1986a, b) opined that in the real world, there are exogenous or nondiscretionary factors of production or outputs that may not be under the control of the management. For example, in agriculture production, the nondiscretionary climatic factor has significant effects on a farm's efficiency level, while it is outside the control of farm mangers and suggested that DEA models should account for the effect of such nondiscretionary inputs and output(s). Similarly, Forsund (2002) opined that the conventional assumption that all inputs and outputs are continuous in DEA models was wrong. He argued that in practical applications, some variables could take the categorical form.

The main characteristic of a producer' reference technology is the applicable type of return-to-scale (RTS) associated with the producer. Hence, the RTS generally, refers to the impact on output when there are changes in inputs employed by the producer. Thus, it replicates what happens to output when there are changes in all inputs or one component. Two broad and common dimensions of RTS, which are associated with *T* include: - constant returns-to-scale (CRS) and variable returns-to-scale (VRS). Constant return-to-scale implies that, output changes proportionally in response to changes in vector of inputs. Thus, output increases or decreases as vector of inputs increases or decreases with an equivalent magnitude and in the same direction.

However, the variable returns-to-scale means that output changes in more proportion than the change in input. The VRS type models as applied in efficiency estimations are namely, increasing returns-to-scale and decreasing returns-to-scale. Increasing returns-to-scale technology is feasible when output (s) increases or decreases by more than the proportional increase or decrease in the vector of inputs. Conversely, decreasing returns-to-scale represents the condition where output increase or decrease in less proportion than the increase or decrease in vector of inputs (Ramanathan, 2003).

The production orientation or plan of producers is also an important component of efficiency measure in a DEA structure. This represents the behavioral assumptions or the production plans of producers. Thus, two production plans applicable to producers are: input-orientation and output-orientation. Input orientation assumption assumes that, a producer seeks to minimize quantities of input employed in production without changing output produced. It addresses the question: By how much can input quantities be proportionally reduced without changing output produced? Alternatively, output-oriented assumption states that a producer seeks to maximize proportionally increase in output with a given level of inputs. Thus, it addresses the question: By how much can output produced be increased without altering the input quantities? Cullinane; et al; (2006) opined that the former is closely related to operational and management strategies by a firm, while the latter is more related to planning and macroeconomic strategies in production planning and management.

Researchers have measured efficiency performances of firms using the DEA approach by systematically applying different categories of efficiency measurements. First is the nonradial efficiency measure, which allows for nonproportional adjustments in inputs or outputs. Second is the slack-based efficiency measure that can be constructed directly from slacks in inputs and outputs. Others are hyperbolic efficiency measure (graph measure) that simultaneously reduce inputs and expand outputs and directional distance function (DDF) efficiency measure, which allows for expansion of desirable outputs but reducing inputs or undesirable outputs at the same time (Zhou, Ang, & Poh, 2008). However, the most widely used type of efficiency measure of the performances of DMUs in DEA models is radial efficiency that adjusts inputs or outputs proportionally.

Thus, researchers combining the radial efficiency measure technique with applicable RTS can estimate DMUs efficiency performances. Thus, the two common DEA techniques used in the literature are:-DEA-CCR and DEA-BCC. These two models were the focus of this study using two-stage DEA estimation technique. As such, in the first stage, the two models were applied to estimate the technical, allocative and economic efficiency scores of paddy rice farmers in Nigeria. While the technical efficiency scores of the respondent rice farmers were estimated using the production function, the economic efficiency scores were estimated using the cost function. The allocative efficiency was derived as a residual using the scores of technical and economic efficiency measures.

Estimation of technical efficiency. The DEA-CCR model introduced by Charnes et al. (1978) assumes constant returns-to-scale for the DMUs reference technologies such that all observed combination of productions can be scaled up or down by DMUs proportionally. The linear programming solution is estimated with either an input-orientation or output-orientation or both. The DEA-BCC models associated with Banker, Charnes and Cooper (1984) allows for the variable returns-to-scale assumption for the producers' reference technologies. Thus, the linear programming solutions are therefore, estimated with input- and/or output-orientations also. In this study, the DEA models employed were: DEA-CCR and DEA-BCC. However, the estimation used only the input-oriented production plan for the paddy rice farmers in Nigeria. This assumed that paddy rice farmers in Nigeria were only interested at minimizing the use of inputs without changing the quantity of rice output.

Therefore, the input-oriented technical efficiency used for the estimation of efficiency scores of the rice farmers is illustrated in Figure 4. Assuming the paddy rice producer used an input vector X^A to produce rice output Y^A, implying that the farmer is technical inefficient. To reduce the technical inefficiency, the inputs can be contracted radially by reducing inputs proportionally from X^A to $\theta^A X^A$ without changing initial output Y^A. On the contrast, if the paddy rice farmer was using input vector X^B or X^C, then there are no opportunities of contracting radially the inputs because the input vectors were originally on the production possibility frontier.

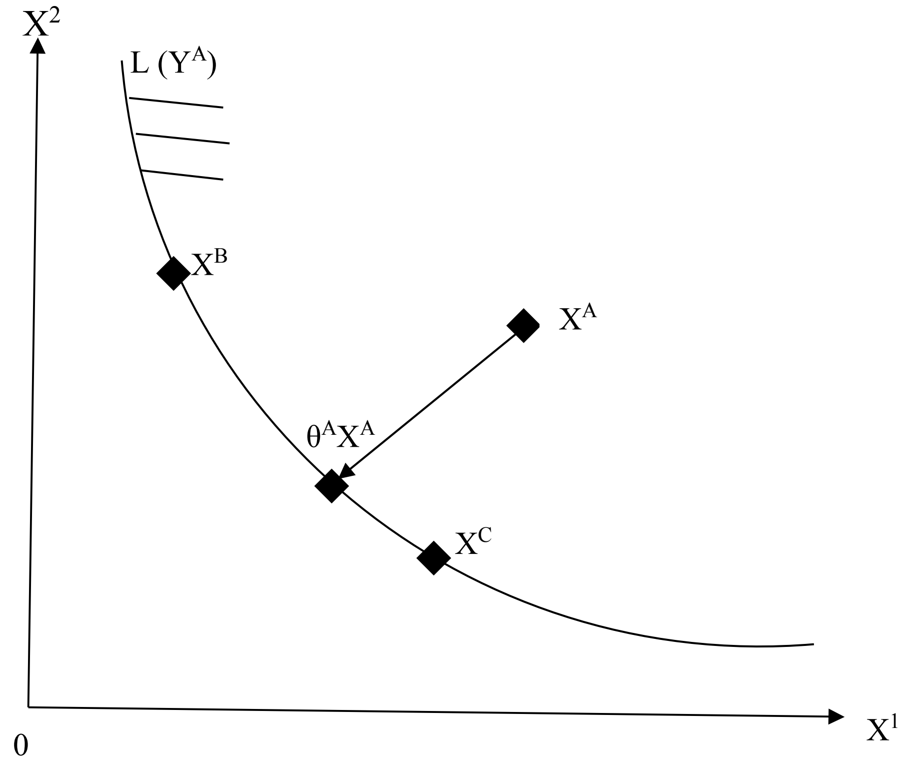

Figure 4. Input-oriented measure of technical efficiency
Adapted from '' Introduction to data envelopment analysis and its uses: With DEA Solver Software and References (Repost)'' by Cooper, W. W., Seiford, L. M. & Tone, K., 2006, New York, NY: Springer, p.7.

Two possible choices were considered for the estimation of the rice farmers' technical efficiency scores. First was to adopt only the CRS or the VRS assumption and second was to consider using both assumptions. In the literature, the production frontier under CRS condition is assumed to be a linear line from the origin. In this case, the input-oriented technical efficiency (T_n) is equal to the output-oriented technical efficiency (T_o). An illustration in Figure 5 showed that the paddy rice farm A is technically inefficient since output lies below the possible production frontier. This means that the farm is using more inputs to produce lower output. The input technical inefficiency can be reduced from

A to A^1_{CRS} or the producer can expand output from A to A^0, using the same quantity of input vector. Thus, the input reduction distance from A - A^1_{CRS} is deemed to be equal to the output expansion distance from A - A^0.

In contrast, the production frontier under the VRS condition takes a convex curve from the origin. Hence, the input-oriented technical efficiency is assumed not to be equal to the output-oriented technical efficiency. Furthermore, Figure 5 illustrates the relationship between technical efficiency and the VRS assumption for producers. Paddy rice Farm A is technically inefficient as it is producing at a point that lies below the production possibility frontier. This means that it can produce the same output by reducing the input vector from point A to point A^1_{VRS} that is within its frontier. Alternatively, it can expand output from A to A^0, using the same level of input vector. However, the input reduction distance from A - A^1_{VRS} is deemed not to be equal to the output expansion distance from A - A^0.

Thus, the conclusion is that the CCR_{CRS} focuses on the objective evaluation of the global technical efficiency of a producer, while the BCC_{VRS} provides estimates of pure technical efficiency given the scale of operations. In this case, the scale efficiency of a producer is calculated as a ratio of the CRS efficiency score to the VRS efficiency score. However, this was the main justification for the choice of using the CRS and VRS assumptions for the production technology of the paddy rice farmers in this study. In other words, the intention was also to determine the scale efficiency scores of the rice farm households, in addition to the technical efficiency scores of individual rice farmers as well as the respective average scores of the entire respondents:

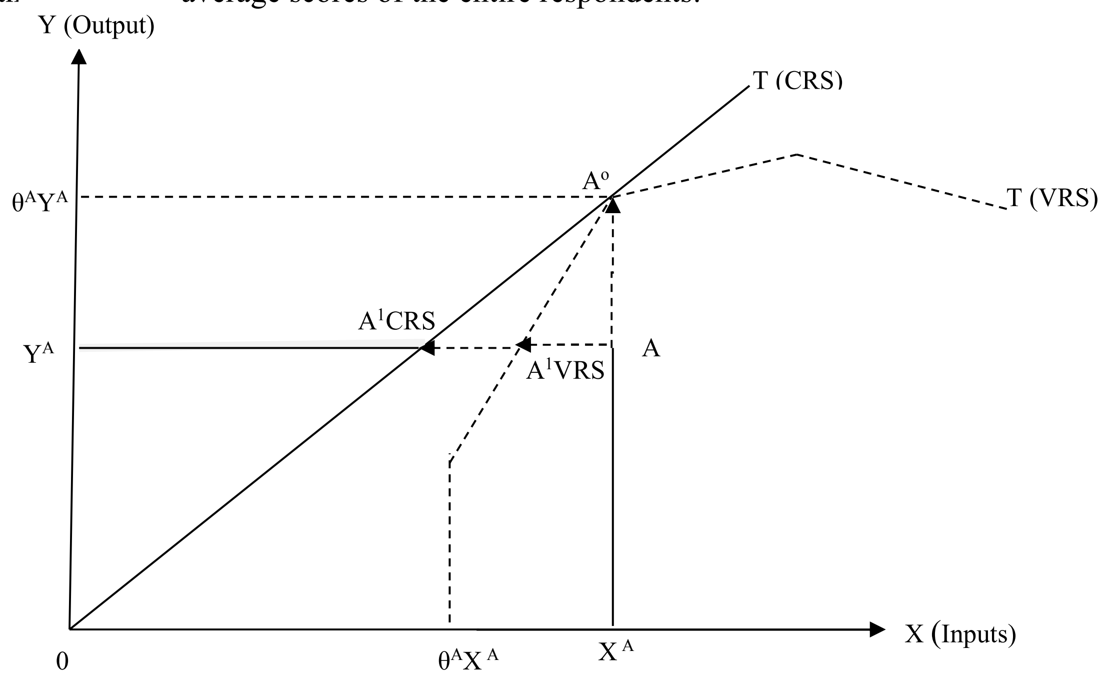

Figure 5. Returns– to-scale and technical efficiency
Adapted from '' Introduction to data envelopment analysis and its uses: With DEA Solver Software and References (Repost)'' by Cooper, W. W., Seiford, L. M. & Tone, K., 2006. New York, NY: Springer, p.86.

Following Taraka, Latif and Shamsudin (2010) and Ceyhan and Hazneci (2010) the input-orientation for the DEA-CCR and DEA-BCC models were employed to estimate the technical efficiency (TE_n) of the paddy rice farmers in the samples. Therefore, the linear programming was formulated by assuming that farm i produces single paddy rice output denoted as y_i and using an input vector also denoted as x_1 to x_n. Thus, the input-oriented model for both the VRS and adjusted for CRS condition is expressed as:

$$TE_n \quad \min (\theta_n) \qquad (12)$$

$$\lambda_i \; \theta_n$$

Subject to:

$$\sum_{i=1}^{I} \lambda_i x_{ij} - \theta_n x_{nj} \leq 0$$

$$\sum_{i=1}^{I} \lambda_i y_{ik} - \theta_n y_{nk} \geq 0$$

$$\sum_{i=1}^{I} \lambda_i = 1$$

$$\lambda_i = 0$$

Where: i = one to I producer; j = one to J inputs; k = one to K outputs; λ_i = non-negative weights attached to i^{th} DMU; x_{ij} = amount of j inputs applied by producer i; x_{nj} = amount of j inputs used by n producers; y_{ik} = amount of k output produced by producer i; y_{nk} = defined as amount of K output produced by n producers and θ_n = defined as input-oriented technical efficiency scalar under assumption that, it lies between $0 \leq \theta_n \leq 1$. If a constraint of $\sum_{i=1}^{I} \lambda_i = 1$ is imposed, it means that TE_n is estimated under variable return-to-scale production technology assumption, thus implying that the model uses the DEA-BCC input-oriented model. However, when this constraint is omitted for $\sum_{i=1}^{I} \lambda_i \geq 0$, then the DEA estimations use DEA-CCR input-oriented model, assuming a constant return-to-scale production technology for the paddy rice farmers.

Estimation of DEA cost efficiency. Assuming that our producers were allocatively inefficient (price inefficiency) but technically efficient. This means that they are economically inefficient in the use of respective production technologies. In this study, the theoretical construct for economic efficiency of paddy rice farms started by first understanding the underlying cost structure, and after established the least cost frontier.

Thus, the construction of the cost frontier was based on the understanding of the behavioral objectives of cost minimization of the paddy rice farmers since input quantities, output quantities and input prices were known. Producers' cost minimization objective was premised on the assumption that paddy rice farms are operating in a competitive market and they were price takers as such no single producer could influence prices in the market. However, in the short-run, the reference production technologies of producers had a combination of fixed and variable costs.

Indeed, total cost structure comprised fixed costs and variable costs but in the long run, all costs are classified as variable costs. Cost minimization will therefore occur at a point where the slope of firm's isoquant line is equal to the ratio of input prices (see Figure 2). Therefore, cost minimization by a paddy rice farm is feasible when relative factor costs (the economic rates of substitution i.e. the rate at which factors are substituted for one another without changing costs) is equal to the ratio of technical substitution (rates at which factors are substituted for one another without changing output) and is also defined as the elasticity of substitution for all i and j input prices. A pre-condition for cost minimization objective implies that the isocost curve (representing the combination of inputs based on relative prices) is tangent to an isoquant at a maximum output (Wetzstein, 2012).

Formally this is expressed as:

$$\text{Min: } w^T x \tag{13}$$

$$\text{Subject to: } f(x) = y$$

Following the Lagrangian and first order conditions:

$$L(\lambda, x) = w^T x - \lambda (f(x) - y)$$

$$w = \lambda \nabla f(x^*)$$

So for any i and j inputs prices:

$$\frac{w_i}{w_j} = \frac{\partial f(x^*)/\partial x_i}{\partial f(x^*)/\partial x_j}$$

The scalar λ represents the increase in cost, when y increases by one unit known as the marginal cost (MC). This is also defined as additional cost incurred due to an increase in additional unit of output and is represented by $\frac{dTC}{dQ} = \frac{\Delta TC}{\Delta Q}$, where TC is total cost expenditure and Q is total output. For emphasis, a firm cost is minimized where the RTS given by $\frac{\partial f(x^*)/\partial x_i}{\partial f(x^*)/\partial x_j}$ is equal to the ratio of inputs i and j prices also given by $\left(\frac{w_i}{w_j}\right)$

Thus, the cost efficiency of a producer can be decomposed into two components: technical efficiency and input allocative (price) efficiency as shown in Figure 6. First, the paddy rice farm A used an input vector X^A with unit input prices W^A, amounting to a total production cost of $W^{AT}X^A$. If the producer decides to adjust the technical inefficiency, it reduces the input vector radially from X^A to $\theta^A X^A$ and used production cost of $W^{AT}\,\theta^A X^A$. At this point, the producer is deemed to be technically efficient but not cost efficient. The producer can adjust the production input vector to X^*, while maintaining a lower production expenditure of $W^{AT}X^*$ to produce the same quantity of output. This means that the cost efficiency of the producer is the ratio of production cost at input vector X^* to the production expenditure at input vector X^A, which is given by $W^{AT}X^*/ W^{AT}X^A$.

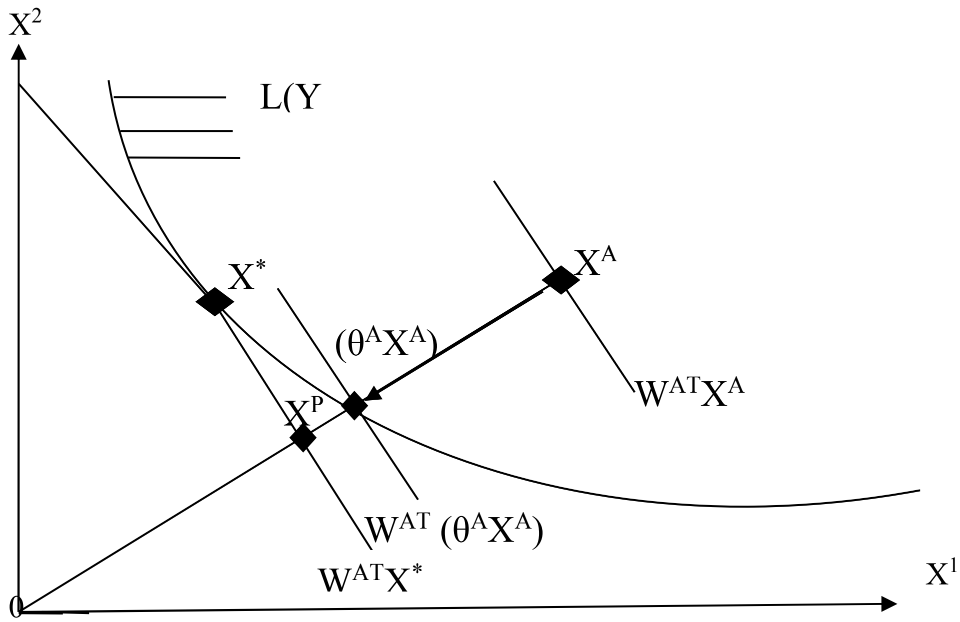

Figure 6. A graph showing the measurement and decomposition of cost efficiency Adapted from ''Stochastic frontier analysis'' by Kumbhakar, S. C., & Knox, L, C., 2003, Cambridge University Press, p. 52.

Therefore, the least cost frontier of the producer can be illustrated as in Figure 7. This showed that the producer will remain cost efficient by reducing the input use from X^A to X^* , while at the same time the farmers is required to reduce the production expenditure from $W^{AT}X^A$ to $W^{AT}X^*$

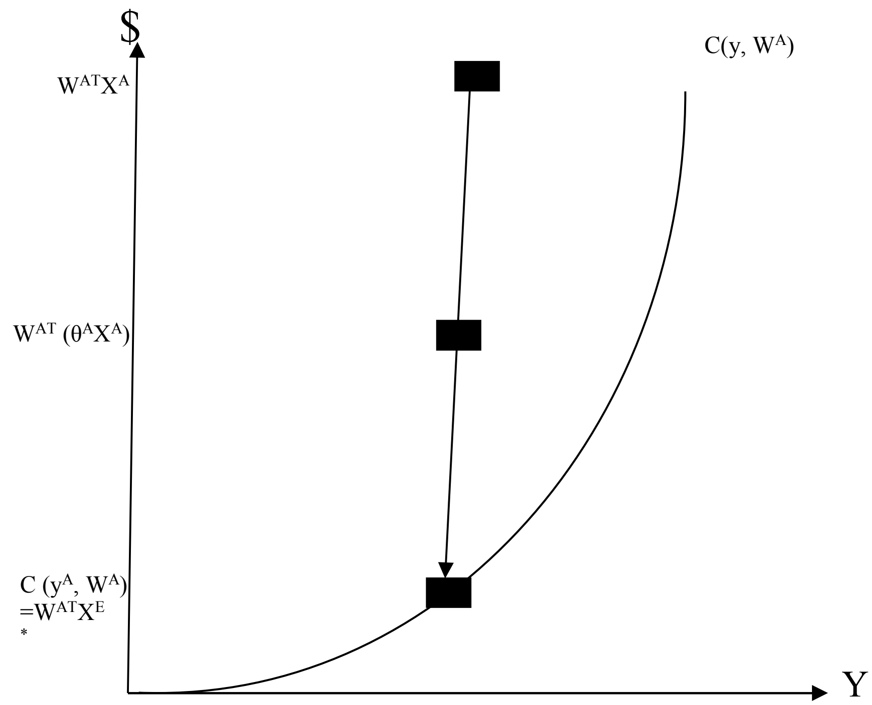

Figure 7: Cost frontier and measurement of cost efficiency
Adapted from ''Stochastic frontier analysis'' by Kumbhakar, S. C., & Knox, L, C., 2003, Cambridge University Press, p. 52.

Thus, an optimal cost objective function for paddy rice farms under the DEA model is solved assuming that $x*_{nj}$ represents the least cost frontier that n firm seek to minimize for a level of input j. While y is paddy rice output produced, p_{nj} is price for input j by firm n. Thus, the cost minimization problem is written as:

$$MC_n = \min_{\lambda_i x_{nj*}} \sum_{j=1}^{j} p_{nj} x_{nj} * \qquad (14)$$

Subject to:

$$\sum_{i=1}^{I} \lambda_i x_{ij} - \theta_n x_{nj} \leq 0$$

$$\sum_{i=1}^{I} \lambda_i y_{ik} - \theta_n y_{nk} \geq 0$$

$$\sum_{i=1}^{I} \lambda_i = 1$$

$$\lambda_i = 0$$

Where: MC_n = minimum total cost for n producers, i = 1 to I producers; j = 1to J combination of inputs; k = 1 to K outputs; xij = amount of inputs j used by producer i; xnj = amount of input j used by producer n; yik; = amount of output k produced by ith producer; ynk = amount of output k produced by n producers; and λi is non-negative weights for i DMU. When a constraint $\sum_{i=1}^{I} \lambda_i = 1$ is imposed on the reference technology, then the estimation of the cost efficiency is performed, using the VRS assumption.

Unlike technical efficiency estimation where researchers could use both CRS and VRS assumptions, the cost efficiency estimation usually applies only the VRS assumption (Sylva Portela & Thanassoulis, 2010). Thus, the economic efficiency for i^{th} producer is defined as a ratio of the least cost to observed cost and is expressed as:

$$EE_{VRS} = \frac{\sum_{j=1}^{J} p_{nj} x_{nj}^{*}}{\sum_{j=1}^{J} p_{nj} x_{nj}} \qquad (15)$$

Finally allocative efficiency of producers is obtained by dividing the score for economic efficiency by the scores of technical efficiency as shown below:

$$AE_{VRS} = \frac{EE_{VRS}}{TE_{VRS}} \qquad (16)$$

Parametric Models

Generally, estimations of parametric models uses OLS, corrected ordinary least square (COLS), modified ordinary least square (MOLS), generalized method of moment estimators and maximum likelihood estimators (Balogun & Ogheneruemu, 2012; Belotti, Daidone, & Ilardi, 2012). However, stochastic frontier modeling in recent years has gained popularity. Specifically, in this study the stochastic specifications of the production and cost functions used the Cobb-Douglas production and the translog cost functional specifications.

SF models. From statistical point of view, the SF approach is implemented by specifying regression models with composite error term. The composite error term comprised idiosyncratic disturbance term, which captures the measurement errors and statistical noise in production data and the one-sided disturbance term, representing the inefficiency term of producers. Whether cross-section, panel data, production and cost or profit frontiers, and time-invariant or varying inefficiency, parametric SF models are regularly estimated using maximum likelihood estimators and maximum log-likelihood-based estimation procedure in particular. The ML estimation of stochastic technical and cost frontiers of producers uses two sequential steps: first, it estimates the model parameters $\left(\hat{\theta}\right)$ by maximizing the log-likelihood function as follows:

$$\ell\,(\theta) \text{ for } \theta = \left(\alpha, \beta', \sigma_{\mu}^{2}, \sigma_{v}^{2}\right)'. \qquad (17)$$

In general, the likelihood function relies on assumption of the independence of the two composite error terms. Since the composite model error is defined as $\varepsilon_i = v_i - u_i$, the joint probability density function of the two is a convolution of both densities, which is expressed as:

$$\int_0^{+\infty} \int u(u_i) \int v\left(\varepsilon_i + u_i\right) du_i \qquad (18)$$

Econometricians however, prefer to work with natural logarithms of the likelihood function, i.e. log-likelihood function (Myung, 2003). Thus, the log-likelihood function for our i paddy rice farm is given as:

$$\ell\,(\theta) = \sum_{j=1}^{n} \log f_{\varepsilon}\left(\varepsilon i \middle| \theta\right) \qquad (19)$$

In the second step, point estimates of inefficiency for DMUs are calculated using the mean or mode of the conditional distribution of u_i given ε_i, and is expressed as:

$$f\left(\mu_i \middle| \hat{\varepsilon}_i\right), for\, \hat{\varepsilon}_i = y_i - \hat{\alpha} - x_i' \hat{\beta} \qquad (20)$$

The second step is necessary because estimation of parameters of the model in the first step only allows for estimating the parameters of the production technology and the residuals ε_i, while producer's-specific inefficiency is not estimated. In other words, the second step of the two-sequential step enables a researcher to separate the unobserved component (inefficiency) from the composite error term. Thus, the point inefficiency score is calculated from the mean or the mode of the conditional distribution of u_i.

Structure of SF models. The structure of the SF models employed to estimate the stochastic production and cost functions are represented by different functional forms of production technology. The common functional forms of production technology applicable in stochastic and other regression based empirical estimations are: linear, Leontief, Cobb-Douglas, translog functions, among others (Greene, 2008). However, the widely used production and cost functions are: Cobb-Douglas and translog production and cost functions. Translog production and cost function introduced by Christensen, Jorgenson, and Lau (1971) is however less restrictive and more flexible functions when compared to Cobb-Douglas production or cost function introduced by the famous economists, Cobb and Douglas (1928). The Cobb-Douglas production function relates output to the geometric mean of inputs, represented in a generalized form as:

$$y = \beta_0 \prod_i^L x_i^{\beta_i} = 0 \qquad (21)$$

$$= \beta_0 * x_1^{\beta_1} * x_2^{\beta_2} * x_3^{\beta_3} \ldots * x_L^{\beta_L} = 0$$

Where: y is the output, β_0 is a scaling factor, representing a constant relationship between each factor of production and output; the x_i values represent a vector of inputs of each factor of production (i.e. labor, capital, etc.); β_i exponents are "output elasticity'' for labor and capital, representing a measure of percentage increase in output due to a percentage increase in particular input and, Π symbol represents the product operator. For y equals to zero, then β_0 must be zero or any of x_i must be zero.

Neo-classical two-factor Cobb-Douglas production function assumes positive and diminishing marginal returns with respect to factor inputs, constant returns-to-scale, no unobserved inputs, substitution of inputs and perfect competition. These assumptions, in essence, restrict the elasticity of substitution of inputs to values of between zero and one and their sum equal to one (Hajkova & Hurnik, 2007). Since Cobb-Douglas production function assumes a constant return-to-scale, meaning output changes in the same proportion as inputs increase or decrease. Thus, the RTS is the sum of elasticity of output for inputs and is defined as $RTS = \sum \beta_i$. Similarly, the elasticity of substitution for the cost function is defined as the ratio of marginal products of inputs to their price ratios, assuming that factor allocations are efficient. Elasticity of substitution between inputs i and j is written as:

$$\sigma_{ij} = \frac{d\left(\frac{x_i}{x_j}\right)}{d\left(\frac{w_j}{w_i}\right)} * \frac{w_j / w_i}{x_i / x_j} = \frac{\beta_i}{\beta_j} * \frac{\beta_j}{\beta_i} = 1 \tag{22}$$

However, in the literature, the production and cost functions are generally specified in log-linear forms either as a Cobb-Douglas or translog model specification as in Agom et al. (2012). For example, the log-linear Cobb-Douglas production function generalized form is denoted as:

$$\ln y_i = \beta_0 + \sum_{i=1}^{N} \beta_n \ln x_i \tag{23}$$

The log-linear form depicts the input-output relationship, which allows econometricians to estimate the parameters of the production technology (β) effortlessly. This production function reflects the ability of producers to technically use minimal level of inputs to produce maximum output. Thus, the application of the Cobb-Douglas production function was applied in this study and was used to estimate the technical efficiency of the paddy rice farm households, while the translog cost model specification of paddy rice farming households in Nigeria was used to estimate the cost frontier.

According to Coelli (2000), the Cobb-Douglas production function remained today the most reasonable approximation of the true production functions. The Cobb-Douglas production function has received specific criticisms. These criticisms are: the inherent assumption in the functional form stating the possible separablity of outputs and inputs. Therefore, the application of the Cobb-Douglas production could generate the problem of endogeneity bias. Second is the incorrect specification of curvature of production frontiers as having a concave structure , while in reality and in all practical cases it is found to be convex.

Estimation of technical efficiency. Stochastic production frontier therefore measures the distance of producers output from the expected frontier or maximum output (Huang, Chiang, Chen, & Chiu, 2010; Nwaobiala & Ume, 2013). As a starting point, using the production possibility frontier of an i^{th} producer as described in equation 23, the observed output of a producer must lie on the production frontier or below it. Therefore, a production frontier of a producer i can be expressed as:

$$y_i = f(x_1, \beta).TE_i \quad (24)$$

As yi is the scalar output of producer i (for i = 1... I), f(x1, β) is the production frontier, while x_i is the vector of inputs applied by producer i, and β are the parameters of the production technology to be estimated. TE_i is the technical efficiency level of producer i. Put simply, the technical efficiency of the paddy rice farm household is determined by a ratio of actual output (yi) to maximum feasible output attainable by the paddy rice farmer, which is represented by the deterministic kernel [$f(x_i, \beta)$]. Therefore, this is expressed as:

$$TE_i = \frac{y_i}{f\left(x_i, \beta\right)} \tag{25}$$

Equation 25 shows that, if $TE_i = 1$, then $y_i = f(x_i, \beta)$, otherwise TE< 1, then the entire deviation is attributed to technical inefficiency assuming that the estimation is deterministic. Introducing the producer-specific random shocks in equation 26, transforms the model specification into a stochastic production frontier, and this is denoted as:

$$y_i = f\left(x_i, \beta\right).\exp\left[v_i\right].TE_i \tag{26}$$

Here, $f\left(x_i, \beta\right).\exp\left[v_i\right]$ is the stochastic production frontier and comprised two parts: the deterministic part $f\left(x_i, \beta\right)$, which is common to all producers and, the $\exp\left[v_i\right]$, which is producer specific, encompassing all effects of random shocks that is randomly distributed across producers. Accordingly, equation 26 can be written in a stochastic technical efficiency form as:

$$TE_i = \frac{y_i}{f\left(x_i, \beta\right).\exp\left\{v_i\right\}} \tag{27}$$

If $TE_i = 1$, then $y_i = f\left(x_i, \beta\right).\exp\left\{v_i\right\}$, otherwise for $y_i < f\left(x_i, \beta\right).\exp\left\{v_i\right\}$, which means there is a shortfall of observed output in an environment that is characterized by random shocks, which are outside the control of producer from the maximum output attainable. In this study, the stochastic production function specification of technical efficiency was applied and this is expressed below following equation 27:

$$TE_i = \frac{y_i}{f\left(x_i, \beta\right).\exp\left\{v_i\right\}} = \frac{\exp f\left(x_i, \beta\right) + v_i - u_i}{\exp f\left(x_i, \beta\right) + v_i} = \exp\left(-u_i\right) \tag{28}$$

Where: $TE_i = \exp. (-\hat{u}_i)$ and is described as producer specific technical inefficiency

estimate. Since we need $TE_i \leq 1$, then $u_i \geq 0$, when it takes the value of zero, then the farm is assumed to be fully technical efficient and otherwise, then $y_i < y^*$.

Using an appropriate log-linear Cobb-Douglas single output stochastic production function for a cross-section of homogeneous paddy rice farm households, the log-linear, first, the deterministic equation on the technical efficiency of paddy rice farms is written as:

$$\ln y_i = \beta_0 + \beta_1 \ln x_{1,} + \ldots\ldots\ldots, \beta_n \ln x_n - u_i \qquad (29)$$

The linear regression model has a nonpositive disturbance term where $u_i \geq 0$, so that, $y_i \leq f(x_i; \beta)$, which is the deterministic kernel, β's are the parameters of the production technology or the *output elasticity* of independent variables, x_i are input quantities and residual is u_i. Introducing the stochastic element possibly captures all random shocks and others, therefore equation 29 can be written as:

$$\ln y_i = \beta_0 + \beta_1 \ln x_1 + \ldots\ldots\ldots, + \beta_n \ln x_n - \varepsilon_i \qquad (30)$$

$$\varepsilon_i = u_i + v_i$$

The composite error term is separated into two components such that ui represents technical inefficiency and v_i captures incidences of measurement errors and others, which is distributed across producers randomly. Therefore, the functional relationship of Cobb-Douglas stochastic production frontier can be written as.

$$\ln y_i = \beta_0 + \beta_1 \ln x_1 + \ldots\ldots\ldots, + \beta_n \ln x_n + v_i - u_i \qquad (31)$$

Stochastic production frontier estimators assume that the error term is composite, consisting of two parts as earlier explained.

Maximum likelihood estimator was explored to estimate the parameters of the production technology as well as the residuals (Afriat, 1972). Therefore, using ML estimators implies that βs in equation 32 are estimated with log-likelihood function in which $\sigma^2 = \sigma^2_v + \sigma^2_u$ and $\lambda^2 = \sigma^2_u / \sigma^2_v \geq 0$. The estimation uses two-sequential steps: first, the log-likelihood function of I producers are maximized as:

$$\ln(yi, \beta, \sigma, \lambda) = -\frac{1}{2}\ln\left(\frac{\pi\sigma^2}{2}\right) + \sum_{i=1}^{I} \ln\Phi\left(-\frac{\varepsilon_i\lambda}{\sigma}\right) - \frac{1}{2\sigma^2}\sum_{i=1}^{I}\left(\varepsilon_i^2\right) \qquad (32)$$

Here $\Phi(.)$ is the cumulative density function (CDF) of standard normal distribution, λ is the scale parameter, and σ^2 is the variance showing fluctuations of the frontier. When λ = 0, it means all deviations from the stochastic production frontier is attributed to random shocks and noise error term and not as a result of technical inefficiency. Thus, reflecting all producers in industry as *super efficient*.

In general, the objective of efficiency estimation goes beyond obtaining the parameters of production technology to an evaluation of producers specific production performances. Thus, in the second step, the estimation of point estimates of technical inefficiency for DMUs is undertaken. These are calculated through the mean of the conditional distribution of u_i given ε_i. To estimate these, the ML estimator splits the residuals (ε) obtained in the first stage into the two common component parts ($\varepsilon_i = v_i - u_i$).

When the point estimate of producer's technical inefficiency (u_i) is obtained, then each producer's technical efficiency score can be derived as in equation 33 below:

$$\_eff = \exp(-\hat{u}) \qquad (33)$$

Where $\hat{u}$ is obtained from the mean, Ĕ $(u/\hat{\varepsilon})$. Thus, the level of technical inefficiency of a paddy rice farm could be determined by estimates of ε_i. Since $\varepsilon_i = v_i - u_i$, if $E(v_i) = 0$, and $\varepsilon_i > 0$, then there is the chance that u_i is insignificant, therefore the producer could be described as relatively technically efficient. Conversely, if $\varepsilon_i < 0$, and $E(v_i) = 0$, also there is the chance that the value of u_i will be large and again, the producer could be described as relatively technically inefficient.

It is a rule that the estimation of stochastic efficiency level of a producer require that econometricians make specific assumptions on distribution of the one-sided error term unlike in the DEA approach. Aigner, Lovell and Schmidt (1977) pioneered the argument on the statistical need to attach distribution assumptions of the one-sided error term. They postulated that disturbance error term is normal half-normally distributed. Stevenson (1980) however, proposed normal truncated-normal distribution of the composite error term, and Greene (1990) preferred to use normal-gamma distribution assumption. Beckers and Hammond (1987) suggested the application of normal-exponential distribution.

All the distributions have specific characteristics associated with the distribution of v_i and u_i components of composite error terms. But common among all the assumptions is the independence of the error components. As such, the joint probability distribution function (PDF) of the error terms is therefore the product of the two individual densities.

The major differences between them however, are the assumptions of the distribution of component error terms. For instance, normal half-normal distribution assumes that $v_i \sim$ i.i.d (N, σ^2_v) and u_i as a non-negative half normal that is $u_i \sim$ i.i.d $N^+(0, \sigma^2_u)$, normal-truncated-normal distribution makes the assumption that $v_i \sim$ i.i.d (N, σ^2_v) but $u_i \sim$ i.i.d $N^+(\mu,\sigma^2_u)$, normal-exponential distribution assumes that $v_i \sim$ i.i.d (N, σ^2_v) and $u_i \sim$ i.i.d exponential. Finally normal-gamma distribution assumes the following characteristics for $v_i \sim$ i.i.d (N, σ^2_v) and $u_i \sim$ i.i.d gamma.

Notwithstanding these differences, there is a general consensus that there are no priority reasons about the choice of one distribution form over the other or choosing the two combinations or all of the assumptions of distribution of the disturbance term since all have their merits and demerits. However, theoretical and practical knowledge are the guiding principles for most researchers in making a choice. According to Coelli et al. (2005), the need for parsimony justifies the choice of less complicated assumptions, *ceteris paribus*. Therefore, they opined that, the normal half-normally and normal-exponential distributions of the one-sided error term have simpler structures and are best options for estimating efficiency of stochastic production and cost frontiers. In the spirit of the debates, the two distribution assumptions namely; half-normal and normal-exponential were used for the estimation of the stochastic Cobb-Douglas production function, while only the normal half-normal distribution assumption was applied in this study to estimate the stochastic translog cost function.

Jondrow, Lovell, Materov and Schmidt (1982), developed a technique known as JLMS, which is an indirect method of estimating inefficiency effect. The method assumed that if $u_i \sim N^+(0, \sigma^2_u)$ i.e. half-normal distribution of inefficiency term (u_i), then the conditional distribution of u_i given ε_i is denoted as:

$$f(u \mid \varepsilon) = \frac{f(u,\varepsilon)}{f(\varepsilon)} \qquad (34)$$

The joint density function of u and ε is represented by $f(u,\varepsilon)$, while the marginal density function of ε is $f(\varepsilon)$. Following Kumbhakar and Lovell (2003), a convenient parameterization is where $u_* = -\varepsilon\sigma_u / \sigma^2 and \sigma_*^2 = \sigma_v^2 / \sigma^2$ as u_* and σ_* .are the estimates. Thus, for a cross-section data equation 34 can be written as:

$$f(u \mid \varepsilon) = \frac{1}{\sqrt{2\pi\sigma_*}}.\exp\left\{-\frac{(u-\mu_*)^2}{2\sigma_*^2}\right\} \Big/ \left[1-\Phi\left(-\frac{\mu_*}{\sigma_*}\right)\right] \qquad (35)$$

Since $f(u \mid \varepsilon)$ is distributed as $N^+\left(0,\sigma_*^2\right)$, then inefficiency term can be estimated from the mean and therefore, the estimator is written as:

$$E\left(ui|\varepsilon i\right) = \sigma_*\left[\frac{\phi\left(\varepsilon i\lambda/\sigma\right)}{1-\Phi\left(\varepsilon i\lambda/\sigma\right)} - \left(\frac{\varepsilon i\lambda}{\sigma}\right)\right] \qquad (36)$$

Beckers and Hammond (1987) extended the debate by assuming that u_i is exponentially distributed with β. Therefore, the conditional distribution of u_i on ε_i is assumed to be exponential. Thus, the conditional distribution of u_i given ε_i is given as:

$$E\left(ui|\varepsilon i\right) = \frac{1}{\sqrt{2\pi}\sigma_v \Phi\left(-\mu / \sigma_v\right)}.\exp\left\{-\frac{\left(u - \mu\right)^2}{2\sigma^2}\right\} \quad (37)$$

Where: $f\left(u\right) = \frac{1}{\sigma_u}.\exp\left(-\frac{u}{\sigma_u}\right)$ and $f\left(u \mid \varepsilon\right)$ is distributed a $N^+\left(\mu, \sigma_v^2\right)$. Again the point estimate for producer's inefficiency score can be calculated from the mean and is written as:

$$E\left(u_i \mid \varepsilon_i\right) = \mu_i + \sigma_v\left[\frac{\phi\left(-\mu_i / \sigma_v\right)}{\Phi\left(\mu_i / \sigma_v\right)}\right] \quad (38)$$

$$= \sigma_V\left[\frac{\phi(A)}{\Phi(-A)} - A\right], for$$

$$A = -\mu_i / \sigma_V \, and \, \mu = -\varepsilon - \left(\sigma_v^2 / \sigma_u\right)$$

Thus, the technical efficiency for each producer can be estimated using the formula in equation 33.

Estimation of stochastic cost efficiency. An alternative representation of stochastic production frontiers of producers is the cost function. This means that any errors in optimization objective of paddy rice farm households, whether technical or allocative must show up as higher costs. Therefore, the implication is that the producer is economically inefficient. A translog specification of the stochastic cost function however was applied in this study to evaluate economic efficiency of paddy rice farmers in Nigeria in this study in contrast to the Cobb-Douglas production function used in the estimation of technical efficiency frontier. Replicating the arguments in Idris, Siwar, and Talib (2013) paper, stochastic cost function (CE) for I rice farmers can be estimated as:

$$E_i \geq c\ (y_i, p_i, \beta), \text{ for } i = 1 \ldots I \quad (39)$$

For:

$y_i = (1 \ldots,, K) \geq 0$ and $p_i = (1 \text{-------} k) \geq 0$

Where: Ei = total cost of i[th] producer; yi = vector of output produced by i[th] producer; pi = vector of exogenously determined inputs prices, and therefore c (yi, pi; β) = the deterministic kernel of cost frontier facing all producers, β = vector of cost parameters to be estimated. Thus, deterministic cost efficiency for the i[th] producer is given as:

$$CE_i = \frac{c(y_i, p_i, \beta)}{E_i} \quad (40)$$

Here, it is assumed that the entire excess of input expenditure in the function is attributed to cost inefficiency. Thus, the stochastic cost frontier of producer i can be written as:

$$E_i \geq c(y_i, p_i, \beta).\exp\{v_i\} \quad (41)$$

Where: $\left[c(y_i, p_i, \beta).\exp\{v_i\}\right]$ refers to stochastic cost frontier, comprising of two parts (a) the deterministic part $\left[c(y_i, p_i, \beta)\right]$ common to all the producers, and (b) the producer specific random part given as $\exp\{v_i\}$. All other variables remain the same as previously defined. Therefore, the cost efficiency (CE_i) of producer i can be denoted as:

$$CE_i = \frac{c(y_i, p_i, \beta).\exp\{v_i\}}{E_i} \quad (42)$$

This is defined as the ratio of minimum cost for producer i to attain in an environment characterized by random shocks that are outside the producer’s control to an observed expenditure by the producer. Thus, $CE_i = 1$, if $E_i = c\left(y_i, p_i, \beta\right).\exp\left\{v_i\right\}$, otherwise CE_i is less than 1.

Using the appropriate translog cost function with an input-oriented technical efficiency, the stochastic cost frontier is formulated as:

$$\ln E_i = \beta_0 + \sum_j \beta_1 \ln p_{i,j} + \beta_y \ln y_i + \frac{1}{2} \sum_j \sum_k \beta_{jk} \ln p_{j,i} \ln p_{k,j} + \frac{1}{2} \beta_{yy} \ln y_i \ln y_i + \sum_j \beta_{jy} \ln p_{j,i} \ln y_i + \varepsilon_i \quad (43)$$

$$\varepsilon_i = v_i + \mu_i$$

Thus, equation 43 is re-written as:

$$\ln E_i = \beta_0 + \sum_j \beta_1 \ln p_{i,j} + \beta_y \ln y_i + \frac{1}{2} \sum_j \sum_k \beta_{jk} \ln p_{j,i} \ln p_{k,j} + \frac{1}{2} \beta_{yy} \ln y_i \ln y_i + \sum_j \beta_{jy} \ln p_{j,i} \ln y_i + v_i + \mu_i \quad (44)$$

Assuming a cost function that is linearly homogenous in input prices, the symmetric restrictions require that $\beta_{ij} = \beta_{kj}$ must satisfy the following additional parameter restrictions such that:

$$\sum_j \beta_j = 1, \sum_j \beta_{jk} = 0 \forall k, \sum_j \beta_{jy} = 0 \quad (45)$$

Therefore, the easiest way to handle such restrictions on the parameters of the cost function is to normalize the total cost and other input prices, using one input price for producer i (for i = 1, ..., k). Schmidt et al. (1979) opined that it makes no difference either economically or statistically, about which input price is used to normalize the equation. Thus, assuming linear homogenous set of input prices, equation 44 is formulated as a normalized log-linear translog cost functional form:

$$\ln \frac{E_i}{p_{1,j}} = \beta_0 + \beta_y \ln y_i + \beta_2 \ln\left(\frac{p_{2,j}}{p_{1,j}}\right) + \frac{1}{2}\beta_{yy}(\ln y_i)^2 + \ln y_i + \frac{1}{2}\beta_{22}\ln\left(\frac{p_{2,i}}{p_{1,i}}\right)^2 + \beta_{2y}\ln\left(\frac{p_{2,i}}{p_{1,i}}\right)\ln y_i + v_i + \mu_i \tag{46}$$

Apart from changes in the signs of the two error components, the imposition of the homogeneity restrictions on βs and the requirement of positive skewness of the residuals, equations 31 and 46 are quite similar in terms of interpretations of the composite error terms.

The ML estimator is usually applied to estimate the stochastic cost efficiency frontier and this follows the same procedure with only a normal half-normal distribution assumption of composite error term in this study. The marginal density function for $\varepsilon_i = u_i + v_i$ are given by:

$$\int_0^\infty f(u,\varepsilon)du \tag{47}$$

$$= \frac{2}{\sigma}\phi\left(\frac{\varepsilon}{\sigma}\right).\Phi\left(\frac{\varepsilon\lambda}{\sigma}\right).$$

Where: $\Phi(.)$ and $\phi(.)$ are the cumulative distribution and density functions, respectively.

In addition, $\sigma = \left(\sigma_u{}^2 + \sigma_v{}^2\right), \lambda = \sigma_u / \sigma_v$ while Equation 47 can be interpreted as follows:

When $\lambda \to 0$ then $\sigma^2_v \to +\infty$ or $\sigma^2_u \to 0$. If $\lambda \to +\infty$, then $\sigma^2_v \to 0$ or $\sigma^2_u \to +\infty$.

Accordingly, the hypothesis to be tested is $\lambda = 0$ or alternatively, $\lambda \neq 0$, using the likelihood ratio test.

To estimate the parameters of the translog functional form, the corresponding log-likelihood function for observation i[th] producer is:

$$L = -\left(\frac{1}{2}\right) - \frac{1}{2}\ln(\sigma_v^2 + \sigma_u^2) + \ln\phi\left(\frac{-\varepsilon}{\sqrt{\sigma_v^2 + \sigma_u^2}}\right) + \ln\phi\left(\frac{\mu_*}{\sigma_*}\right) \quad (48)$$

Where:

$$\mu_* = \frac{\sigma_\mu^2 \varepsilon}{\sigma_v^2 + \sigma_\mu^2},$$

$$\sigma_*^2 = \frac{\sigma_v^2 \sigma_\mu^2}{\sigma_v^2 + \sigma_\mu^2}$$

Thus, the log-likelihood of the model is equivalent to the sum of the function for all observations and maximizing the log-likelihood function gives the ML estimates of the parameters of the model. The next step in the ML estimation of the cost efficiency is to obtain point estimates for producers' cost inefficiency. The cost inefficiency is obtained through the information contained in the estimates of ε_i. When E (v_i) = 0, and $\varepsilon_i > 0$, then we have the chance that estimates of u_i is insignificant, and a producer could be described as relatively cost efficient. On the contrary, if $\varepsilon_i < 0$ and E (v_i) = 0, the chance that the value of u_i will be large exists, and a producer could be described as relatively cost inefficient. Thus, a solution to this problem is solved using the conditional distribution of u given ε_i. The JLMS indirect estimation method and assuming that u_i is distributed as $N^+ (0, \sigma^2_u)$, then the conditional distribution of u_i given ε_i is denoted as:

$$f(u \mid \varepsilon) = \frac{f(u, \varepsilon)}{f(\varepsilon)} \tag{49}$$

$$= \frac{1}{\sqrt{2\pi}\sigma_*} . \exp\left\{ -\frac{(u - \mu_*)^2}{2\sigma_*^2} \right\} \Big/ \left[1 - \Phi\left(\frac{-\mu_*}{\sigma_*} \right) \right]$$

Since $f(u \mid \varepsilon)$ is distributed as $N^+ (\mu_*, \sigma_*^2)$, then the point estimate of cost inefficiency is calculated using the mean of the distribution as expressed in equation 50:

$$E(u_i \mid \varepsilon_i) = \mu_{*_i} + \sigma_* \left[\frac{\phi(-\mu_{*_i} / \sigma_*)}{1 - \Phi(-\mu_{*_i} / \sigma_*)} \right] \tag{50}$$

Thus, knowing the estimates of the cost inefficiency, then the cost efficiency (CE_i) is obtained using the equation below:

$$CE_i = \exp(-\hat{u}) \tag{51}$$

Empirical Literature on Efficiency

Empirical studies on efficiency estimations usually employ different methods, variables, and production functions to evaluate the level of technical, allocative, economic and scale efficiency scores of producers and to explain the variations of efficiency scores across the producers. This section conducted reviews of these studies in the rice subsector, exposing the methods, specifications of production function as in the SF, characterization of the production technology as in the DEA, distributional assumption as in the SF and empirical results on efficiency estimations of rice farms in different countries. Thus, the reviews of the literature provided the platform for the specifications of the empirical models used in the study. The reviews also revealed some pertinent methodological issues relating to the application of different approaches discussed previously, such as issues relating to forms of data used and the problem of multicollinearity.

Watkins et al. (2014) evaluated the technical, allocative and economic efficiency of rice production in Arkansas, U.S., employing data envelopment analysis (DEA) approach. They applied the input-orientation model, while the CRS and VRS assumptions were used for the reference production technology. The estimation of the economic efficiency scores was also explored using the cost minimization model. The study however, applied a two-stage DEA estimation technique on a panel data of Arkansas paddy rice farmers. The objectives of the study were: first, to examine the relationships between output of rice and the traditional rice production inputs. Second, to examine the relationships between technical, allocative and economic efficiency measures and farmers' specific socioeconomic characteristics, using the Tobit (censored regression) model. Data on output, inputs and input prices were obtained from 158 farmers for the period 2005-2012.

A peek at findings indicated a mean TE_{CRS} score of 0.803 but ranged from 0.380 to 1.000. The mean TE_{VRS} score of sampled rice farmers was 0.875 and also ranged from 0.440 to 1.000 across the rice farmers. On the other hand, the mean allocative efficiency score was estimated at 0.711, which ranged from 0.332 to 1.000. This showed the absence of cost-minimization objective in the utilization of inputs by rice farmers, given relative input prices. Therefore, the study concluded that the rice farmers in Arkansas will need to reduce average costs of operations by approximately 29.0% so as to achieve the same level of output. The mean scale efficiency was estimated at 0.920 but ranged from 0.428 to 1.000. This means that the farmers were close to optimal farm size. In the Tobit model, there were mixed outcomes as some variables performed below a prior expectation, while others behaved according to the expectations.

Baten et al. (2014) assessed technical efficiency of rice production in Bangladesh using stochastic frontier (SF) model. They specified the reference production technology as a Cobb-Douglas log-linear production function with normal truncated-normal and normal half-normal distribution assumptions of the one-sided error term. The main objective of the study was an assessment of changes in rice farms technical efficiency that have occurred over time in Bangladesh. The data used for the study was a panel data obtained from the Yearbook of Agricultural Statistics, Bangladesh. Results of estimated models showed mean technical efficiency of 0.604 for the normal-truncated normal distribution assumption and 0.517 for the normal half-normal distribution assumption. Results also showed the presence of high level of technical inefficiency in rice production in Bangladesh even though over time technical efficiency did improve. The output elasticity for the input variables on technical efficiency however varied. For example, rainfall was found in both distributions negative and insignificant. Thus, confirming the conception that rainfall bears low output elasticity. They reasoned that this was due to the impact of public investment in irrigation schemes that had helped to mitigate the impact of harsh weather conditions. Area, seed and fertilizer were positive and significant at various levels of significance in both assumptions. Fertilizer in urea however, was found to be negative but significant at 1% level in both distribution assumptions.

Idiong et al. (2007) evaluated farm technical efficiency among a cross-section of small scale swamp rice farms in Cross River State, Nigeria. The study was conducted using SF approach and a two-stage estimation procedure. The stochastic production function was specified as a log-linear Cobb-Douglas production function. The models were estimated using ML estimation technique. The study used multistage probability sampling technique for the selection of respondents. A total of 56 small scale rice farms were selected from ten communities across the state. Results indicated a technical efficiency levels for swamp rice farmers in Cross River State, Nigeria, which ranged between 0.48 and 0.99 and the mean technical efficiency was estimated at 0.77. Furthermore, the result revealed that majority of the rice farmers' in the state had low wastage in the use of rice farm inputs. However, the study concluded that small fraction of rice farmers attaining efficiency levels below 50% could improve if they would learn from the superior farmers regarding the appropriate use of inputs for rice cultivation.

Bäckman et al. (2011) opined that rice cultivation in north-central and north-western regions in Bangladesh recorded significant variations in technical efficiency, ranging from 0.16 to 0.94 with mean technical efficiency of 0.83. They suggested that rice cultivation had experienced substantial improvements in terms of technical efficiency over time given the available resources and existing technologies in the country. In the study, the stochastic frontier approach with a normal-exponential distribution assumption characterizing the rice production technology in Bangladesh was used. This was fitted with a log-quadratic production function, following Chu, Aigner and Frankel (1970). The estimation used Frontier 4.1 software but applied a single-stage SFA estimation model.

The panel data for the study were however obtained from sampling units from 12 villages in the north-west and north-central regions in Bangladesh through a survey conducted with structured questionnaires over a period of time. The factors adopted at the second stage estimation to explore the possible reasons for substantial variations in efficiency scores across paddy rice farmers were: age of farmers, level of education, access to extension services, off-farm incomes and experience in rice cultivation. A review of estimation results also showed the estimated parameters of these contextual variables as properly signed to expectations. As such, age, education, number of plots, region (dummy variable), access to microfinance (dummy variable) and off-farm income had positive and significant effects on technical efficiency. However, extension visits and farm experiences of rice farm households had negative but significant effects on technical efficiency contrary to theoretical expectations.

Ahmadu and Erhabor (2012) estimated factors influencing technical efficiency of rice farms in Taraba State, Nigeria, using a stochastic frontier model. The model was fitted with a log-linear Cobb-Douglas production function. The estimation was conducted using the ML estimation technique and two-stage estimation model. Data were collected from cross-section of selected 150 rice-farming households from the three agricultural zones of the state using multiple sampling techniques. About 50 respondents each were selected from the three production systems in the state namely: the upland, lowland and the deep water production systems. To ensure validity of results, the structured questionnaire was adequately evaluated by experts, while it was also pre-tested using a pilot survey before commencement of actual survey and data collection. The estimation results of the study reported significant variations in levels of technical efficiency of sampled rice farmers, ranging from 0.27 to 0.91, with a mean efficiency score of 0.52. However, only age and level of education of sampled rice farmers were found significant at 1% to 5% levels at affecting variations in efficiency scores across rice farmers, while others were marginally significant at 10% level of significance.

Hassanpour (2013) examined the impact of optimal size of paddy rice farms in Kohgiluye-va-Boyerahmad (KB) province in Iran on farm economic efficiency, using the DEA model. The LP was estimated using the production and cost frontiers, while input-orientation model was applied to estimate producers' technical and economic efficiency scores. Data were collected from a cross-section of 132 paddy rice farmers, who were interviewed using a structured questionnaire. An assessment of results reported mean technical, allocative and economic efficiency of paddy rice farmers in KB province at 0.621, 0.743 and 0.446, respectively. The study also noted substantial difference between economic efficiency of the best farmer and the sample mean of 0.55. The study therefore concluded that there is a wide gap between maximum profit attainable and the observed profit.

Hossain, Kamil, Masron and Baten (2013) evaluated the impact of environmental factors on technical efficiency of rice farmers in Bangladesh employing a DEA approach and output-orientation production objective. The estimations were conducted with CRS and VRS assumptions, which were used to characterize the reference production technology of rice farmers. Information on the variables was collected from the Yearbook of Agricultural Statistics, Bangladesh. The estimation used information on three different types of rice produced in Bangladesh - BORO, AUS and AMAN. Environmental factors applied were amount of rainfall, humidity and temperature. A quick glance showed estimated mean technical efficiency for the three categories of rice produced in the country at 0.945, 0.934 and 0.941 for AUS, AMAN and BORO, respectively. The mean scale efficiency scores were 0.950, 0.941 and 0.943 in the same order. The study concluded that there was no significant impact of environmental factors on technical efficiency for the three different types of rice produced. Again, this was attributed to the availability of irrigation facilities, which helped to reduce the impact of harsh environmental conditions in some seasons.

Bamiro and Aloro (2013) examined technical efficiency of rice production in swamp and upland rice production systems in Osun State, Nigeria. The study applied a two-stage SF model and the stochastic production function was specified as a log-linear Cobb-Douglas production function. The study employed proportional sampling procedure to select participants from three key rice producing local governments in the state. Data were then obtained from 198 participating farms using interviews and structured questionnaire. The study employed two different techniques namely, OLS and maximum likelihood estimators to estimate the models. The study predicted technical efficiency range of between 0.48 and 0.71 in the swamp rice production system. The average technical efficiency of entire swamp rice farms was estimated at 0.56. On the contrary, it predicted technical efficiency for upland rice production ranging from 0.77 to 0.99 but had a mean technical efficiency of 0.91.

These estimates reflected substantial differences in technical efficiency between upland and swamp rice production systems in the state. The output elasticity of input variables for technical efficiency for swamp rice production system with exception of fertilizer had significant influence on output. On the other hand, land was the only input resource that had significant influence on upland rice output. Estimations of factors accounting for variations in technical efficiency in upland rice production system showed access to credit as the only factor that influenced variations in technical efficiency. In the swamp rice system, gender was the only significant variable accounting for variations in technical efficiency but had a negative relationship.

Thibbotuwawa et al. (2013) compared similarities and differences of technical, allocative, cost and scale efficiencies between irrigated and rain-fed rice farms in Sri Lanka. The study employed two different frontiers: first, they used a common ‘’meta-frontier’’, which is defined as a boundary of an unrestricted technology set and second a ‘’group frontier’’ also defined as boundaries of restricted technology sets in each group namely irrigated and rain-fed rice farms. The estimations used a DEA approach with an input-orientation procedure and assumptions of CRS, VRS and non increasing returns-to-scale (NIRS). The assessment of economic efficiency was conducted using a nonparametric cost function. However, primary data were collected from a cross-section of 90 farms, randomly selected from a population of farms in six districts in Sri Lanka.

The study reported average technical efficiency, allocative efficiency, cost efficiency and scale efficiency of 0.87, 0.80, 0.69 and 0.92 respectively, with minimum values of 0.55, 0.39, 0.37 and 0.63 in irrigated rice areas. In rain-fed areas, mean scores for technical efficiency, allocative efficiency, cost efficiency and scale efficiency were 0.92, 0.73, 0.67 and 0.92 respectively. Minimum efficiency estimates in rain-fed areas were 0.62, 0.52, 0.48 and 0.63 for technical efficiency, allocative efficiency, cost efficiency and scale efficiency, respectively. However, the study concluded that there was no significant difference between irrigated and rain-fed farms in all the efficiency measures, using the independent *t* test results.

Rahman (2003) evaluated profit efficiency of Bangladeshi rice farms, applying a profit function which was specified as a translog stochastic profit frontier. The study employed a two-stage stochastic profit model. Primary data were obtained from a cross-section of rice farmers through an intensive farm-survey conducted during February to April, in the three agro-ecological regions of Bangladesh. Overall, a total of 406 rice farming households from twenty-one villages were selected, using a multistage stratified random sampling procedure. The data collected included seven conventional inputs and several other background socioeconomic factors affecting variations in production and profit across the respondents.

The result reported high levels of profit inefficiency in rice cultivation in the country. The mean level of profit efficiency was estimated at 0.77. This implied that an estimated 23.0% of anticipated profits to farmers were lost due to a combination of technical and allocative inefficiencies. Several factors accounted for variations in mean profit efficiency scores among rice farmers across the three agro-ecological regions. These factors were: - regional disparities in level of infrastructural development, peculiar regional soil fertility, rice farming experience, access to extension services, land tenancy and share of nonagricultural income

Okeke, Chukwuji and Ogisi (2012) estimated technical and scale efficiencies for a sample of irrigated and rain-fed rice farmers in Anambra State, Nigeria with a DEA model. The DEA model was estimated with CRS and VRS assumptions attached to the reference production technology and also with an input-orientation objective function. Participants were selected for the study using a multiple sampling technique. About 156 rice farmers were randomly selected for the survey, which represented twenty-five each from the six communities sampled. Data were however obtained from sampling units through interviews conducted with structured questionnaire. The analysis of estimation results exposed the need for a significant reduction in input usage at the same level of output. The study therefore suggested that rice farmers' education on modern rice cultivation methods need to be improved upon by government, so as to enable them take these advantages to gain higher productivity. Furthermore, the results reported a mean technical efficiency for the rain-fed rice farming system at 0.588 and scale efficiency was estimated at 0.896. The mean technical efficiency and scale efficiency in respect of irrigated rice production system were 0.776 and 0.951, respectively.

Rahman, Mia, and Bhuiyan (2012) estimated farm-size-specific productivity and technical efficiency of all rice crops in Bangladesh, employing a stochastic frontier model. The twin objectives of the study were to estimate technical efficiency of rice farmers based on the criterion of farm size. Second was to evaluate the causes of variations on the observed technical efficiency scores associated with the sampled rice farmers. The study employed a two-stage SFA technique by first, estimating coefficients of output parameters and producer's technical efficiency. In the second step, they examined the relationships between observed technical efficiency and socioeconomic factors specific to sampled rice farmers. The stochastic production function was specified as a Cobb-Douglas production function, which was used to estimate the technical efficiency and the causes of variations in technical efficiency across the rice farmers.

Primary data were collected from a cross-section of 1,360 farmers, who were selected using multiple sampling techniques. The required information was also obtained from respondents through direct interview method with a means of structured questionnaire. Thus, the study covered four different categories of farm sizes namely large, medium, small, marginal farm and all farms. The parameters of stochastic frontier production function model were estimated using ML and computer program-FRONTIER

Version 4.1. The results of the study showed average technical efficiency scores for large, medium, small, marginal farm and all farms as 0.88, 0.92, 0.94, 0.75 and 0.88, respectively. The maximum efficiency scores attained for large, medium, small, marginal farms and all farms were 0.99, 0.98, 0.98, 0.95 and 0.98, whereas the minimum efficiency scores for the above farms were 0.62, 0.57, 0.70, and 0.34, respectively. Explaining the variations of efficiency across farms, the results reported that factors influencing efficiency vary across different farm sizes.

Nargis and Lee (2013) examined efficiency scores from field-level data of 178 rice farmers, who were selected during 2010 cropping season from some of the major rice growing villages in the Mymensingh district of Bangladesh. The estimation of the model used two-stage data envelopment analysis approach. The technical, allocative, economic and scale efficiency of individual farms were estimated with an input-oriented production and cost frontiers, as well as applied both VRS and CRS assumptions for the reference production technology. The Tobit model was employed to evaluate the relationships between DEA efficiency scores and all the relevant contextual variables. Primary data were obtained from a field survey during 2010 rice cropping season and covered a cross-section of participants, who were selected randomly from three villages in the Mymensingh district. The study reported average technical, pure technical, allocative, economic, and scale efficiency for BORO (dry season crop) rice farms as 85%, 94%, 85%, 80% and 90%, respectively. For AMAN (wet season crop) rice, efficiency levels of rice farms were estimated as: 79%, 90%, 78%, 70%, and 87%, respectively for technical, pure technical, allocative, economic, and scale efficiency measures.

The results also reported considerable inefficiencies in producing BORO and AMAN rice. Farm input use ratios showed that farmers were overusing inputs and also employing an incorrect input mix in both seasons. Tobit regression results also indicated that efficiencies of farms were influenced by farmer's level of education, family size, land tenancy, seed type, household head occupation, access to extension services, farmer type (water buyer or seller), irrigation type (shallow tube well or deep tube well) and sources of energy for BORO rice. In the case of AMAN rice production, farmer's level of education, family size, land tenancy, plot size, seed type and access to extension services, mass media and land degradation also created variations in efficiencies of rice farms.

Tung (2013) examined typical changes that have occurred over the years in technical and scale efficiencies in rice production in the Mekong delta region in Vietnam. They applied a single bootstrapping data envelopment analysis (DEA) model to estimate levels of efficiencies among the rice farmers in the region. The model for technical efficiency measure was estimated using an input-orientation production objective. The FEAR 1.0 software package was used to estimate the TE_{CRS}, TE_{VRS} and TE_{NIRS} scores, using the DEA model. To explore the variations in technical efficiency among the rice farmers the bias-corrected TE_{VRS} was applied as the dependent variable and were regressed against eight independent variables in a truncated regression model. The secondary data for the estimations were obtained from the Vietnam General Statistics

Office (GSO), which span from 1998 to 2010. The sample comprised 1000 rice farming households, who were used to create the panel data.

The study reported substantial changes in technical efficiency during the period of estimations and these changes were characterized as increasing return-to-scale (IRS). For example, the mean bias-corrected variable returns-to-scale for rice production increased during the period of estimation, rising from 0.484 in 1998 to 0.606 in 2010. This reflected an increase of 25.2% for the twelve year period or an average annual growth rate of 2.5%. However, from the truncated regression, the impact of socioeconomic factors on variations on technical efficiency varied from year to year. The popular factors were: age, gender and ethnicity, marriage status of household head, household size and economic status of the household head as well as the proportion of income from growing rice as a proportion of total income.

Taraka, Latif and Shamsudin (2010) assessed average technical efficiency of rice farmers in Central Thailand at 0.587, which ranged from 0.30 to 1.00 for VRS assumption. For the CRS assumption, the mean efficiency was estimated at 0.517. The scale efficiency was estimated at 0.998. Overall, about 50% of paddy rice farmers in the region have efficiency scores less than 0.60. Therefore, the study reported the presence of low efficiency in rice production in the area. The major factors influencing variations in efficiencies among the rice farmers were: family labor, access to extension service, and certified seed, problem of pest, weed and insect control. The technical efficiency scores were estimated using a DEA approach and an input-oriented model, while estimation for the impact of socioeconomic factors on technical efficiency scores was conducted using the Tobit model. Primary data were obtained from cross-section of 400 rice farming households, using a multistage random sampling procedure.

Chowdhury, Rumi and Rahman (2013) engaged stochastic frontier model to measure the efficiency scores of rice farmers during BORO period in Bangladesh, and to evaluate major factors that accounted for variations in farm efficiency during the same period. The components of rice production efficiency measures used were: - technical, allocative and economic efficiency measures. Likewise, the study applied Cobb-Douglas production and cost frontiers to compute technical, allocative, and economic efficiency scores. Unlike others that used SFA, the determinants of variations in inefficiency were estimated using Tobit model. Primary data were collected from a cross-section of participants from three different districts in the High Barind area of Bangladesh. The reported results showed that the mean efficiency for technical, allocative, and economic efficiency of rice farms during BORO period were 0.860, 0.750, and 0.640, respectively.

Ogundele and Okoruwa (2014) investigated levels of technical efficiency and productivity growth, respectively, among rice farmers in Nigeria, using simultaneously the SFA and DEA approaches. In the SF approach, they assumed that the stochastic production frontier takes a Cobb-Douglas log-linear production function form. The ML estimation technique was applied to estimate the parameters of rice farmers' production technology. The twin objectives of the study were: first, the measurement of technical efficiency, and second, the determination and disaggregation of productivity growth between 2003 and 2007. In the DEA approach, the study explored the application of Malmquist TFP index to estimate technical efficiency under the assumptions of VRS and CRS and also using input-orientation production objective. The data used for estimation were retrieved from household survey panel data for 2002 and 2007. The SFA method employed FRONTIER 4.1 software, while DEAP 2.1 software was used to examine technical efficiency and productivity changes, using Malmquist index technique.

The mean technical efficiency of rice farmers from the DEA model estimation with an assumption of CRS was 0.66 and 0.53, respectively for periods 2002 and 2007. Under the VRS assumption, the average efficiency was estimated at 0.856 and 0.570, respectively for 2002 and 2007. Analyzing SFA results, average technical efficiency in 2002 and 2007 using FRONTIER 4.1 showed high technical efficiencies of rice farms, compared to DEA estimates. For instance, SF model reported technical efficiency of 0.987 and 0.847 for the periods of 2002 and 2007, respectively. These high levels of technical efficiency scores by SF approach suggested super-efficient rice farmers as against the results of DEA model, which reported high inefficiencies among Nigerian rice farmers. The ML estimations of output elasticity of inputs showed land, labor in man-days, seed and fertilizer had coefficients of 0.145, 0.156, 0.427 and 0.742, respectively and were positive and significant at between 1% and 5% significance levels.

Kadiri et al. (2014) explored the use of SF model to estimate technical efficiency of rice farmers in the Niger Delta region in Nigeria, using a translog production function. The study further assessed factors which could explain the variations in technical efficiency of sampled rice farms. Multistage sampling technique was used to collect information from 300 respondent rice farms from the six states in the region. The estimation was also conducted with ML estimation technique and log-likelihood ratio was applied to test the hypotheses. The study revealed a mean efficiency for rice producers in the Niger Delta region at 0.63. All coefficients of rice farm inputs were found to have positive influences on paddy rice productivity and they ranged from 0.384 to 0.941. The results further explained that 90% of rice farmers had technical efficiency scores above 0.50. The study concluded that, majority of rice farmers were technically efficient in resource utilization.

The study further indicated that gender and household size were significant determinants of variations in technical efficiency of rice farms in the Niger Delta region. The study however recommended policies targeted at ensuring low and affordable costs of productive inputs to farmers and improving households' income through minimum guaranteed prices for the output. Provision of labor saving equipment was a key success factor, which could help in reducing inefficiencies in paddy production by reducing labor cost.

Omondi and Shikuku (2013) applied stochastic Cobb-Douglas production function to assess how best rice farmers in Ahero Irrigation Scheme in Kenya have performed. Thus, they estimated producers' technical efficiencies and evaluated factors affecting observed variations in rice farms' efficiency scores among the Ahero rice farmers. A household questionnaire was used to collect primary data from rice farmers in Ahero irrigation scheme during the month of April 2012. The sampling frame for the study was obtained from the Ahero regional office. Stratified and random sampling techniques were used to select eight agricultural blocks out of existing twelve blocks.

Probability proportionate to size sampling technique was also employed to give a sample size of 220 rice farmers from whom data were collected using structured interviews. The study reported significant coefficients for inputs such as fertilizer and labor with positive influences on paddy rice producers' technical efficiencies. However, chemical use had negative influence on paddy producers' technical efficiencies. The mean technical efficiency of rice farmers was estimated at 0.82 but ranged from 0.30 to 0.95. The study concluded there was need for most rice farms to reduce input use by almost 18%. It further reported the significant determinants of variations in technical efficiency across rice farmers. These include; gender, farming experience, income level and distance to market.

Ismail, Idris and Hassanpour (2013) investigated the extent paddy rice farmers in the peninsular Malaysia are technically efficient. They used comparative methods of SF and DEA models. With the DEA model, output-oriented model was used to estimate levels of technical efficiency while applying only the VRS assumption. In SF model, the production function was specified as a translog production function. The production function was appended with a specification of normal half-normal error term distribution assumption. The primary data were obtained from a cross-section sample of 230 paddy rice farmers during 2010 farming season. The participants were selected randomly and proportionally from east and west peninsular Malaysia. Information was collected through a survey, which used direct interviews and structured questions. The results from the analysis of data showed difference in results obtained from the different methodologies. The DEA result showed a mean efficiency score for rice farmers in Peninsular Malaysia as 0.560, while the SFA result reported higher mean technical efficiency score of 0.690.

Assessment of the Literature Review

A quick glance of results and ratings from empirical efficiency literature in the rice subsector from different countries so far, showed the convergence of results (see Table 25). Of the twenty studies reviewed, eight of these studies reported using mainly data envelopment analysis (DEA) approach, ten used strictly stochastic frontier models and two engaged the combinations of DEA and SF models, simultaneously. Most of these studies examined technical efficiency measure using input-oriented models to estimate efficiency levels. However, two applied output-oriented model to estimate technical efficiencies of rice farms (Ismail et al., 2013).

Evidences so far converge to a conclusion that rice farmers generally were operating below the efficient frontier because the mean technical efficiency ranged from 0.484 to 0.990. Some of these studies also estimated allocative and economic efficiency scores either using the cost or profit functions. Overall estimates suggested some levels of allocative and economic inefficiency, meaning that rice farmers were overusing inputs based on relative factor prices and were far below the attainable profit levels. About five of these studies evaluated scale efficiency (SE) of rice farming households, which showed marginal variations across countries. The SE varied between 0.895 and 0.980, indicating very small and less than 10% average scale inefficiency of rice farmers across the countries (Okeke et al., 2012; Taraka et al., 2010). The central lesson from these empirical studies suggested the presence of productive inefficiency in paddy rice production by farmers globally but the level varied from country to country.

A critical assessment of these studies however has raised some pertinent methodological issues. First is the choice of estimation methods of production efficiency of rice farms. The main approaches so far in the literature are: SF and DEA models with several extensions. From the same literature, there is no general consensus on a system of estimation, which provides better, reliable and consistent estimates. Each of these approaches has its own merits and demerits and several extensions have been applied by researchers. The choice of an approach is at the prerogative of a researcher and will depend on his or her technical knowledge. So far, evidences showed that DEA models are producing more conservative, realistic and ostensibly convincing measures of efficiency scores over the SF models (Ogundele et al., 2014).

Aside, DEA models have their own drawbacks compared to the SF. First is its inability to carter for possible influences of measurement errors and other noises inherent in agricultural data. As such, all observed deviations from the estimated frontier are therefore, assumed to be a result of technical, allocative and economic inefficiencies. In other words, DEA model is regarded as a method which suffers greatly from super efficient outliers (Yusuf & Malomo, 2007). Conversely, the stochastic frontier models are applied because they are assumed to carter for these deficiencies inherent in DEA models. This is because the models assume a composite error term comprising inefficiency term and a part that captures the random shocks (Alvarez & Arias, 2014).

Table 21
A Summary of Survey of Empirical Literature

Author	Location	Efficiency Approach	Production Function	Data Set	Efficiency Results
Watkins et al., 2014	Arkansas, USA	Two- Stage DEA with VRS & CRS Assumptions. Second stage- Tobit Model	Input-Oriented and Cost Function Model	Panel Data (2005-2012) and 158 participants	TE_ CRS = 0.803 Range = 0.380 – 1.000 TE_VRS = 0. 875 Range = 0.380 – 1.000 AE = 0.711 Range = 0.332 -1.000 SE = 0.92 Range = 0.428 – 1.000
Baten & Hossain, 2014	Bangladesh	SFA	Cobb-Douglas Distributional Assumptions - Truncated and Half-Normal OLS and MLE	Panel Data 1980-1981 2008-2009 Data from secondary sources	TE_Truncated = 0.604 TE_Half- Normal = 0.517
Idiong et al., 2007	Cross Rivers State, Nigeria	SFA with two-stage modeling	Cobb-Douglas MLE	Cross Section, Multistage sampling-56 participants	TE = 0.770 Range = 0.480 – 0.990
Bäckman et al., 2011	North-central & North-west regions, Bangladesh	SFA with an exponential assumption Single-stage estimation	Log- quadratic production function Frontier 4.1 Software	Cross Section, Multistage sampling	TE = 0.830 Range = 0.160 – 0.940
Ahmadu & Erhabor, 2012	Taraba State, Nigeria	SFA two-stage modeling	Cobb-Douglas MLE	Cross-section 150 participants Purposive and Random Sampling	TE = 0.520 Range = 0.270 – 0.910
Hossain et al., 2013	Bangladesh	DEA with VRS & CRS, Assumptions	Input-Oriented and Cost Function Model	Secondary Data	TE by Rice Type AUS = 0.945 AMAN = 0.934 BORO = 0.941
Bamiro and Aloro, 2013	Osun State, Nigeria	Two-stage SFA	Cobb-Douglas OLS MLE	Cross-section 190 participants Proportional and Random Sampling	TE by Production System Swamp Rice = 0.56 Range = 0.480 – 0.710 Upland Rice = 0.91 Range = 0.77 – 0.990

(table 21 continues)

Table 21

A Summary of Empirical Literature Survey

Author	Location	Efficiency Approach	Production Function	Data Set	Efficiency Results
Thibbotuwawa et al., 2013	Sri Lanka	DEA Frontiers Meta Group CRS, VRS & NIRS	Input-Oriented and Cost Function Model	Cross-section of 90 participants Random Sampling	*TE by Production System* Irrigation Rice = 0.870 Rain-Fed Rice =0.920 *AE by Production System* Irrigation Rice = 0.800 Rain-Fed Rice =0.730 *CE by Production System* Irrigation Rice = 0.690 Rain-Fed Rice =0.670 *SE by Production System* Irrigation Rice = 0.920 Rain-Fed Rice =0.920
Hassanpour, 2013	KB Province, Iran	DEA	Input-Oriented and Cost Function Model	Cross-section 132 participants Random Sampling	TE = 0.621 AE = 0.743 EE = 0.445
Rahman, Mia, and Bhuiyan, 2012	Bangladesh	SFA two-stage analysis	Cobb-Douglas MLE	Cross-section 1360 participants Purposive. Stratified and Random Sampling Procedures	*TE by Farm Size* Large Farms = 0.880 Medium Farms =0.940 Small Farms = 0.750 Marginal Farms =0.880 *Range of TE by Farm Size* Large Farms = 0.620-0.990 Medium Farms =0.57-0.98 Small Farms = 0.70- 0.95 Marginal Farms =0.34-0.98
Okeke et al., 2012	Anambra State, Nigeria	DEA CRS & VRS Assumptions	Input-Oriented	Cross-section 150 participants Purposive and Random Sampling	*TE by Production System* Irrigation Rice = 0.5880 Rain-Fed Rice =0.776 *SE by Production System* Irrigation Rice = 0.895 Rain-Fed Rice =0.951
Taraka, Latif and Shamsudin, 2010	Central Thailand	Two-stage data envelopment analysis (DEA)	Input-oriented model under the VRS and CRS assumptions. Tobit Model	Cross-sectional data with 400 participants Multistage sampling with stratified and simple random sampling methods	*TE Scores* TEVRS = 0.587 Range: 0.30-1.00 TECRS = 0.517 SE = 0.998 % of Framers with TE scores less than 0.60 is 50%
Chowdhury, Rumi and Rahman, 2013	High Barind area of Bangladesh	SFA two-stage analysis	Cobb-Douglas MLE Tobit Model	Cross-sectional data Multistage sampling with stratified and simple random sampling methods	*TE Scores BORO Period* TE = 0.860 AE = 0.750 EE = 0.640

(table continues)

Table 21

A Summary of Empirical Literature Survey

Author	Country	Efficiency Approach	Production Function	Data Set	Efficiency Results
Nargis and Lee (2013)	Mymensingh district of Bangladesh	Two-stage data envelopment analysis (DEA)	Input-oriented and cost frontier estimation under the VRS and CRS assumptions. Tobit Model	Cross-section 178 participants Random Sampling Procedure	*BORO Rice* Total TE = 0.850 Pure TE = 0.940 AE = 0.850 EE = 0.800 SE = 0.900 *AMAN Rice* Total TE = 0.790 Pure TE = 0.900 AE = 0.780 EE = 0.700 SE = 0.940
Kadiri et al. (2014)	Niger Delta, Nigeria	Approach-SFA	SFA -Translog	Cross Sectional data, multistage sampling – participants = 300	*TE Scores* *TE = 0.63* *Range = 0.384 – 0.941*
Omondi and Shikuku (2013)	Ahero Irrigation Scheme, Kenya	Two-stage SFA	Cobb-Douglas MLE Tobit Model	Cross-sectional data. 220 participants Multistage sampling with stratified and simple random sampling methods	*TE Score* *TE = 0.820* *Range: 0.300-0.950*
Ismail, Idris and Hassanpour (2013)	Peninsular, Malaysia	Multiple Approaches-SFA and DEA	Under SFA -Translog-Half Normal assumption -MLE Under DEA -Output-Oriented Model under VRS only assumption	Cross-sectional data. 230 participants Multiple sampling with proportional, stratified and simple random sampling methods	*TE Score under DEA* *TE = 0.560* *TE Score under SFA* *TE = 0.690*

Notes. TE = technical efficiency, AE=allocative efficiency, EE = economic efficiency, SE=scale efficiency.

To overcome weaknesses inherent in both approaches, researchers have developed several extensions of these models and these are continuously been refined. One major development is the decision of researchers to use either the single-stage or two-stage DEA and SF models. Specifically, using DEA approach, empirical studies have also introduced three-stage DEA models to estimate efficiency scores (Fried et al., 2002). Also, Simar and Wilson (2000, 2007) suggested the applications of bootstrapping as a way of overcoming the problems of measurement errors.

However, the most popular estimation procedures in empirical literature are single-stage and two-stage estimation models. The single-stage models in both approaches use data on outputs, inputs and observable contextual variables all at once in a single model. The objective is to control for the impact of traditional inputs using contextual variables affecting the efficiency levels of producers. Conversely, the two-stage model in both approaches also use data on outputs and inputs to estimate the efficiency levels of producers in the first stage. In the second stage, it uses data on observable contextual variables to account for the variations of efficiency scores of producers obtained in the first stage. In both the DEA and SF models, researchers use regression-based techniques such as OLS, fractional logistic and/or Tobit models to estimate impact of these contextual variables, believing that the model estimation may be capable of attributing some portion of the variations in producers' performances to the effect of statistical noise.

Generally, in both approaches the two-stage approach model has also been criticized and considered as unsatisfactory. There is some consensus that it yields biased estimates of technological parameters. For instance, Wang and Schmidt (2002) provided extensive evidences to show that the size of this bias is relevant and large, and could make the estimation results spurious and therefore, suggested the single-stage model only. Despite the debates, in this study, the two-stage modeling approach was employed to estimate the technical, allocative and economic efficiency scores of rice farmers in Nigeria and to explain the possible variations in technical and economic efficiencies scores across paddy rice farm households, using policy variables and other contextual variables.

Thus, the estimations procedures adopted were as follows: first, the technical, allocative, and economic efficiency scores in DEA and technical and economic efficiency scores in the SF models of paddy rice farms were estimated. The estimates generated from the two approaches were compared while the most reliable estimates were identified. In this consideration, the DEA generated estimates were found to be more reliable statistically and conservative. Second I regressed independently the estimates of technical and economic (cost) efficiency scores obtained in the first stage in the DEA models on identified policy actions/interventions, while controlling with the farm specific socioeconomic. The essence was to identify the impact of policy actions on the respective efficiency scores (Hossain et al., 2013).

In production economics, contextual variables are found to characterize the operational conditions and practices in organizations or businesses (Kronsbein, Meiser & Leyer, 2014). These contextual variables are embedded in the business processes and they account for business or organization performances, while they are classified as either internal or external factors. Internal contextual factors are embedded in business organizational structure, business resources, and customer conditions. Conversely, the external contextual variables are factors that determine business successes, which are largely imposed from outside the business organization. These are political, environmental and economic business conditions. Building on these clarifications, the external dimension of contextual factors in this study, were policy interventions by governments in the rice subsector. The internal factors were classified as the socioeconomic characteristics, which have strong influences on production efficiency scores of rice farms. Following Banker et al. (2008) these variables were classified and measured as categorical and continuous and either at ordinal, interval or ratio levels.

One major area which has produced inconclusive debates by econometricians is the type of regression-based estimators that could be applied in the second stage estimations of the impact of contextual variables on variations in efficiency levels of producers. Tobit model, ordinary least square (OLS), and fractional logistic models are the common estimators applied in the literature to explain the impact of contextual variables on the variations of productive efficiency among producers. For example, McDonald (2009) suggested the use of OLS as a good alternative to Tobit model, if data on the dependent variable are fractional. He opined that in the case of fractional dependent variables, the OLS produces unbiased and consistent estimates, while tests for hypotheses can confidently and convincingly be conducted using *t* tests. This is because all efficiency scores generated in the first stage are possibly descriptive measures at the second stage.

On the contrary, Maddala (1999) and Amemiya (1984) opined that OLS technique produces biased, inefficient and inconsistent estimates of the explanatory variables at the second stage of efficiency modeling. As a consequence, the results obtained from the estimations could be spurious. They instead suggested the application of Tobit model or censored regression, which they assumed tends to produce larger and stable responses of all the explanatory variables. In general, Tobit model is developed for situations where the dependent variable is incompletely observed or where it is completely observed but observed in a selected sample, which does not represent the true population. The Tobit model therefore, handle cases of incomplete observed data either as a result of truncation or censoring. Truncation arises when some data on dependent variable are lost but not on the regressors. Censoring occurs when some data are lost in both the dependent variable and the regressors.

Some researchers have also expressed contrary views against using OLS and/or Tobit estimation techniques and therefore, have suggested the application of a different approach. Ramalho, Ramalho and Henriques (2010) argued in favor of applying fractional logistic model, while stating that the standard linear model is inappropriate because the predicted values of y may lie outside the unit interval and this could imply that the constant marginal effects of covariates are not compatible with the bounded nature of the efficiency scores and the existence of a mass point at unity in their distributions. In other words, they argued that the OLS and Tobit models estimates are biased, inefficient and inconsistent. They also provided reasoned argument showing that the domain of Tobit model differs from that of the efficiency estimations, since in the later efficiency scores of zero or less than zero are really observed. Thus, they recommended the application of fractional regression model (FRM).

The key advantages of the FRM are first, the model exhibits various functional forms, which are flexible in the estimation of a typical asymmetric nature of efficiency scores. Second the fractional regression models are easily estimated with the quasi-maximum likelihood estimator (QMLE). This is an econometric estimation technique applied to estimate the parameters of a model that has no specific assumptions on the distributions of the model error term. Thus, quasi-maximum likelihood estimator becomes the maximum likelihood estimator to be applied to such a model with the alteration that errors are presumed to be drawn from a normal distribution and this often produces consistent estimates (Czado & Haug, 2006). Therefore, the FRM will not require researchers to make assumptions on conditional distribution of efficiency scores.

In the spirit of the debates, in this study I employed the fractional logistic regression model to estimate the variations in technical and economic efficiency scores as explained by public policy variables however, controlled by specific contextual variables in the second stage as in Ramalho, Ramalho and Henriques (2010). Thus, in line with Papke and Wooldridge (1996) proposal, the FRM is estimated by implementing a logistic transformation of the dependent variable. In this case, the dependent variable is transformed from a nonlinear relationship into a linear relationship as it helps to overcome the problem of possible violation of linearity assumptions associated with regression-based models.

The model specification is given by:

$$E\left(y \mid z\right) = G\left(z'\beta\right) = 1\big/\left[1 + \exp\left(-z'\beta\right)\right] \qquad (52)$$

Where: G (.) is a nonlinear function that satisfies $0 \leq G(.) \leq 1$, and the FRM are estimated by quasi maximum likelihood estimator (QMLE) based on the Bernoulli log-likelihood function is given as:

$$LL_i(\beta) = y_i \log\left[G\left(z_i\beta\right)\right] + \left(1 - y_i\right)\log\left[1 - G\left(z_i\beta\right)\right], \text{ for } 0 \leq y_i \leq 1 \qquad (53)$$

Therefore, the parameters of the model are estimated using the binary logistic regression, which maximizes the values of the log-likelihood function.

Another pertinent empirical estimation issue that has been of concern from the literature review is the choice of contextual variables that should be included in the model explaining variations in efficiency scores among homogenous producers. Most empirical studies had applied broadly socioeconomic, environmental and management practices to explain variations in the scores of observed technical, allocative, economic and scale efficiency scores of producers. Socio-economic characteristics were described in this study as internal contextual variables affecting the efficiency scores of paddy rice farmers in Nigeria. These variables are found to be important factors influencing production decisions in rice farms. For example, specific socioeconomic characteristics of the paddy rice farmers are factors that help to shape the perceptions and attitudes of producers and to a large extent could have substantial influence on production efficiency of paddy rice farms (Ojo et al., 2013).

The socioeconomic characteristics of rice farming households that had often be included in the empirical studies are: age of rice farmers, household size, education and gender status of head of households; land tenancy type, membership of cooperatives and/or other groups, marital status, farm experiences, means of transportation, distance to farm and size of plot. However, some researchers have also included access to farm extension services, credit, government subsidized inputs such as fertilizer and other chemical use, and government guaranteed minimum price and storage facilities, land as well as access to government pest, weed and insect control programs as socioeconomic variables impacting on paddy rice farm production efficiency scores.

However, Hossain et al. (2013) opined that the applications of these factors by researchers in the literature in the past had received different treatments. Thus, in the context of this study, access to farm extension services and government subsidized inputs such as fertilizer and other chemical use were described as policy related variables from government. This is because they are deliberate interventions by governments, which were considered as exogenous to the paddy rice farms that could help to improve technical and cost efficiencies, hence enhance annual paddy rice output. Therefore, the interest in this study revolves around the impact of these contextual policy interventions on efficiency scores and output of paddy rice farmers.

Overall, the approach used in this study was to identify access to above mentioned policy interventions as the policy independent variables. Contrary to some other studies, these policy independent variables were controlled with the specific socioeconomic characteristics attached to individual paddy rice farms. Thus, in the second stage of the two-stage, these variables were included in the models as control variables basically to underscore the true effects of access to government interventions to the observed technical and economic efficiency scores of paddy rice farm households in Nigeria using the three selected states: Kaduna, Nassarawa, and Niger States.

Another methodological problem in the empirical efficiency estimation is the concern about the form of data used. Two forms of data were commonly used in empirical efficiency studies namely; cross-section and panel data. Cross-section data cover only one observation point usually, a calendar year. This form of data only takes a snapshot of producers' performances in a given time period. On the contrary, panel data cover more observation points and obtain information on DMUs over a period of time (i.e., more than one period). Thus, the panel data format produces producers' performances over a longer period. The results emanating from panel data could explain changes in efficiency and productivity over time, which is vital for policy evaluation. However, in the agricultural sector, studies on performances of farm households have relied more on cross-section data due to the absence of reliable agricultural data over time in most developing countries. Based on this reason, in this study, I explored the use of cross-section data to evaluate the impact of policies on the three measures of production efficiency in the three selected states in Nigeria.

In regression based production efficiency estimations, a major issue researchers have to grabble with is the problem of multicollinearity. This problem occurs when two or more predictor variables are inter-correlated or are dependent on each other (El-Fallah & El-Salam, 2013). Multicollinearity can cause large variations in the estimated parameters making them deviate from true values of the population parameters by orders of magnitude or incorrect signs. In most cases it inflates the variance of estimations and therefore, has the potential for influencing most of the regression results such as the Eigen structure. Thus, the presence of multicollinearity in estimated models indicates that there is a chance that the estimated standard errors could be inflated as they are very sensitive to changes in the sampled observations.

Field (2009), and El-Fallah and El-Salam (2011) identified some errors responsible for the presence of multicollinearity: first, is when a variable in a model is computed from another predictor variable. Second is the improper use of dummy variables in models, which could lead to perfect collinearity among the predictors. These errors could be avoided if the researcher can do the following: exclude one of the predictor variables although it could cause model specification error, find another indicator to define the concept to be measured and collect larger sample of participants. The use of larger sample size helps to reduce the problem of multicollinearity because it increases the degree of freedoms and equally reduces the standard errors.

Conclusion

The chapter explained some stylized facts about Nigeria as well as the structure of the rice value chain. The structure and trends of rice consumption and production were reviewed. The analysis showed substantial self-sufficiency gap, which is persistently filled by rice import. The conclusion drawn was that the continuous massive importation of rice is unsustainable and an unacceptable situation. No wonder the Federal Government has initiated policies and interventions to tackle the menace. These policies are aimed at enhancing production efficiency of paddy rice farmers in Nigeria.

Following the policy review, the chapter highlighted the focus of the study, which is to evaluate the impact of policies on production efficiency of rice farms across selected states in Nigeria. The preliminaries on production theory were also discussed as a guiding framework for efficiency estimations in this study. Review of approaches to efficiency estimations indicated the two complementary methods that were used in the study. The review of past studies in the rice sector also revealed some pertinent methodology issues regarding efficiency analysis. Following the empirical literature review, critical assessments of pertinent methodological issues, which are main issues in the measurement of technical, allocative, and economic efficiency were explained.

Chapter 3 discusses the research method used in the study. Thus, it presents the intended research design and survey method, sampling strategy and settings, sample size, data collection and instrumentation, validity and reliability of results, ethical considerations, definition of variables, model specifications and data analysis methods and procedures. It utilizes multiple sampling, analytical and empirical models to provide answers to the research questions.

This study employed a quantitative approach using a cross-section survey to collect primary data from selected units of analysis mainly paddy rice farm households in the three selected states. Multiple probability sampling techniques were employed to generate the number of sampling units/sample size for each state, reflecting about 100 participants in each state and a total of 300 participants for the entire survey. The sample size for each state was determined using a sample size formula instead of a sample size table. The use of the sample size formula was as a result of absence of adequate information of paddy rice farm households population in each of the selected states. Data collection was by means of structured interviews of the selected paddy rice farm households. The data were collected using a structured questionnaire that covered five components. To ensure validity and reliability of results, adequate steps were taken to ensure a scientific approach in selection of participants and conformity of the questions to empirical literature.

Chapter 3: Research Method

Introduction

This chapter presents a detailed discussion of the methodology used in this study of household rice paddy farming in Nigeria. Chiefly, it discusses the research design, sampling strategy, sample size, data collection and instrumentation, actions taken to achieve validity and reliability of results and outcomes, ethical considerations, definitions of variables and models specifications. In this study, a triangulation approach was employed to investigate the research questions at each stage. This was justified because multiple techniques were used at each stage of this study to ensure confident and convincing findings, as recommended by Frankfort-Nachmias and Nachmias (2008).

In this context, the study engaged multiple sampling techniques to select participants, while each state sample size was determined using the Cochran (1963) sample size equation. Overall, 100 participants were selected from each state thus, making a total sample size of 300 participants. In terms of data instrumentation, a structured questionnaire was used, while the primary data was obtained using an interview technique. I also employed multiple estimation methods to evaluate the impact of policies on technical and economic efficiency scores of paddy rice farms from the Nigerian states of Kaduna, Nassarawa, and Niger. The estimation methods employed were the DEA and the SF approaches to generate the technical, allocative and economic efficiency scores. Also, the fractional logistic regression model was applied to evaluate the impact of policies on the estimated technical and economic efficiencies.

Research Design and Approach

This study employed a quantitative approach using a cross-section survey to collect primary data from selected units of analysis. A quantitative study was most appropriate for the research study because it allows for the measurement of relationships between two variables (Chipuunza & Berry, 2010; Frankfort-Nachmias & Nachmias, 2008). The use of a qualitative research study approach would not have been appropriate as such studies are usually based on words not numbers, and on exploration, not connections (Frankfort-Nachmias & Nachmias, 2008). Thus, the research design provided a basis for generating numeric analysis of the characteristics of the population, using samples that represented the population.

I specifically explored and selected a cross-section design because it facilitated making a snapshot evaluation of the research questions at a particular point in time in 2014/2015 rice cropping season. Utilizing this research method produced some inferences on the pattern of causal relationships between government policies and technical, and economic efficiency measures of paddy rice farms in Nigeria (Chipuunza & Berry, 2010; Frankfort-Nachmias & Nachmias, 2008). The choice of a cross-section survey was also informed by the absence of appropriate time series data on activities of rice farming households, who are spread across the federated states in Nigeria. The unreliable data series available at the selected States' Ministries of Agriculture did not provide enough information to construct reliable panel data. In this circumstance, the best option was the application of cross-section data covering the 2014/2015 farming season.

The units of analysis in this study were the population of paddy rice farmers operating in Nigeria's Kaduna, Nassarawa, and Niger states. The population of rice farming households in each of the state formed the sampling frames in respective sampled states from where the samples were drawn. The findings and conclusions drawn from the samples of the population were further generalized to the entire population after adequate tests in the study were established.

Sampling Strategy and Setting

I employed multiple probability sampling techniques to generate the number of sampling units/sample size for each state. This involved the use of stratified sampling, cluster sampling, and simple random sampling procedures (Chipuunza & Berry, 2010). The survey generally covered three states, representing two geopolitical zones in Nigeria out of six. The sampling procedure for the selection of states engaged the stratified sampling technique based on the criterion of states' contributions to the national rice output in 2013.

I selected three states from the two geopolitical zones for this study's survey of paddy rice farming households. This selection was made based on information in Table 3, Table 13, and Appendix A; thus the selected states were Kaduna, Nassarawa, and Niger. The general background information of the selected states is presented in Table 22, while the sampling strategy used is discussed below. Each of the state was stratified into three agricultural zones from where two to four local government councils were selected from each agricultural zone based on the criterion of their respective shares to the state paddy rice output. Overall, 26 local governments were selected out of a total of 61, representing 42.6% of the number of local governments in the sampled states, while it constituted about 3.4% of the 774 local government areas nation-wide.

Table 22

Socioeconomic Characteristics of Selected States

Indicators	Niger	Kaduna	Nassarawa
Geopolitical Zone	North- Central	North- West	North- Central
# of LGAs	25	23	13
Land Mass (thousand Km^2)	84.0	46.10	28.70
Population(million)	3.96	6.10	2.00
Gross Domestic Product (2010 in $billions)	6.00	10.33	3.02
Per Capita Income per annum ($)	1515.2	1666	1588
Average Temperature per annum	32^0C	40^0C	34^0C
Average Annual Rainfall per annum	1600mm	1,600mm	1500mm
% of Farming Population	80.0	60+	60+
% Rice Farming Population	30.0	40.0	45.0
No. of Agricultural Zones	3	3	3
% of rice output to national output	16.0	20.2	3.7
% of rice output to regional output	47.8	68.9	10.7
Major rice producing system	Lowland	Lowland	Upland

Note. Data compiled from survey returns from respective States' Agricultural Development projects (ADP).

I selected the survey circles/villages from the sampled local government areas, representing the paddy rice farming villages, using a cluster sampling technique. The sampling units (paddy rice farmers) were further drawn from the rice producing circles/villages, using a simple random sampling technique based on the sampling frame provided by the respective states' ADPs. Further details of the state-by-state sampling methodology are provided below:

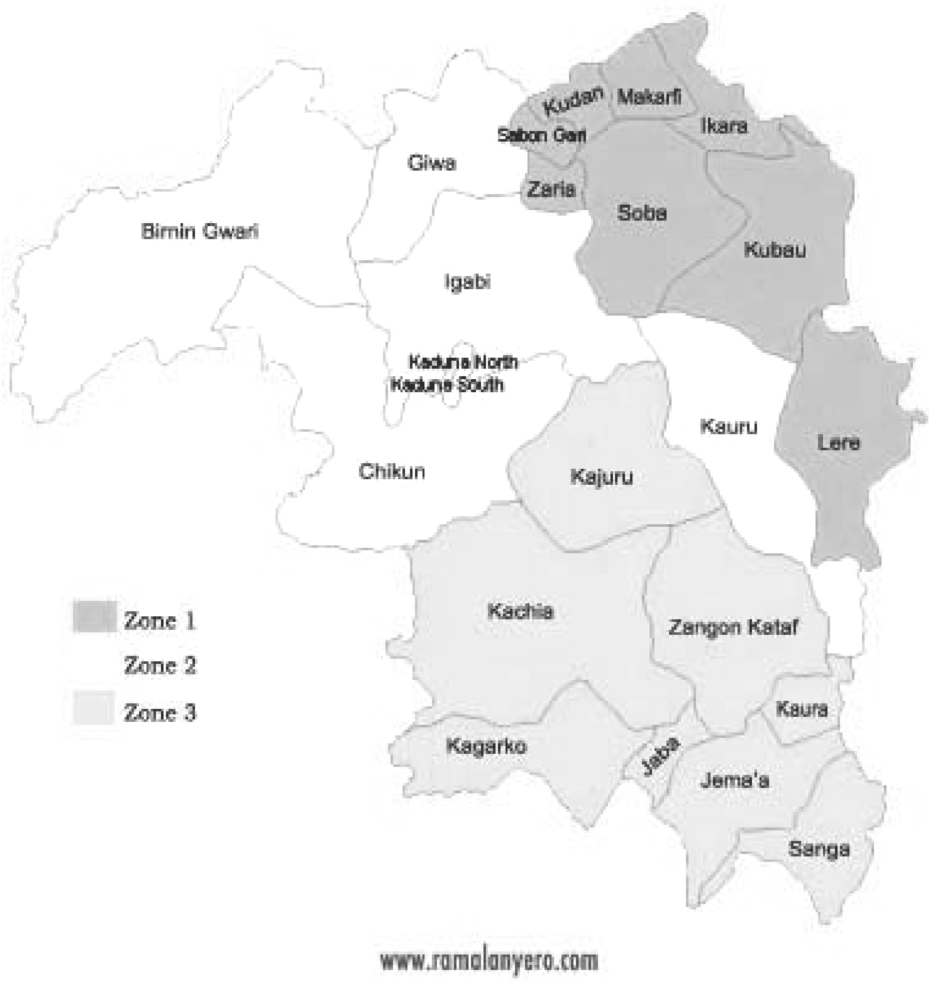

Figure 8. Map of Kaduna State.
Note. The map was obtained from the office of Kaduna State Agricultural Development Project

Kaduna State. Figure 8 shows the map for the state including the agricultural zones and the allied local government councils. The three agricultural zones of Maigana (Zone 1), Birni-Gwari (Zone 2) and Samaru (Zone 3) were used as the basis for the selection of local government areas in which the survey was conducted. A total of eight local governments areas (LGAs) were sampled from the three agricultural zones in the state during the survey. The distribution of the local governments across the agricultural zones was as follows: Maigana (2), Birni-Gwari (2), and Samaru (4). Similarly, the lists of the local governments selected during the survey in the state by agricultural zone were: Maigana (Zaria and Sabon-Gari); Birni-Gwari (Kaduna South and Chikun) and Samaru (Kaura, Zango-Kataf, Jema'a, and Kajuru). A total of 14 villages were also drawn from the 8 local government areas for the survey from where the participants were chosen using a simple random sampling procedure. The sampling frame was obtained from the Kaduna State Agricultural Project.

Figure 9. Map of Nassarawa State.
Note. The map was obtained from the office of Nassarawa State Agricultural Development Project

Nassarawa State. The sampling strategy in Nassarawa State is illustrated in Figure 9. Figure 9 shows the map and the associated local councils by agricultural zones in Nassarawa State. However, in each of the agricultural zone, a basic feature of the sampling strategy adopted was the selection of three local government areas from each zone and this was based on their respective shares of rice production in the state rice output as at 2015.

Thus the three agricultural zones namely, southern, central and western zones were selected while 9 LGAs were sampled using a stratified sampling technique. The distribution of the local governments across the agricultural zones was as follows: Southern Zone (Obi, Doma, and Lafia); Central Zone (Akwanga, Wamba, and Kokona) and Western Zone (Nassarawa, Keffi, and Karu). Overall, 9 rice production circles/villages were selected from the respective local governments for the conduct of the survey in the state from where the participants were drawn using a simple random sampling procedure and the sampling frame provided by the Nassarawa ADP.

Niger State. The same procedures used in the two former states were also employed in Niger State, which include stratified sampling, cluster sampling and simple random sampling procedures. Figure 10 illustrates the sampling strategy showing the map and the linked local councils by agricultural zones in Niger State. As in Nassarawa, the strategy in each agricultural zone was to select three local government areas from each zone and this was based on their respective shares of rice production in the state rice output as at 2014.

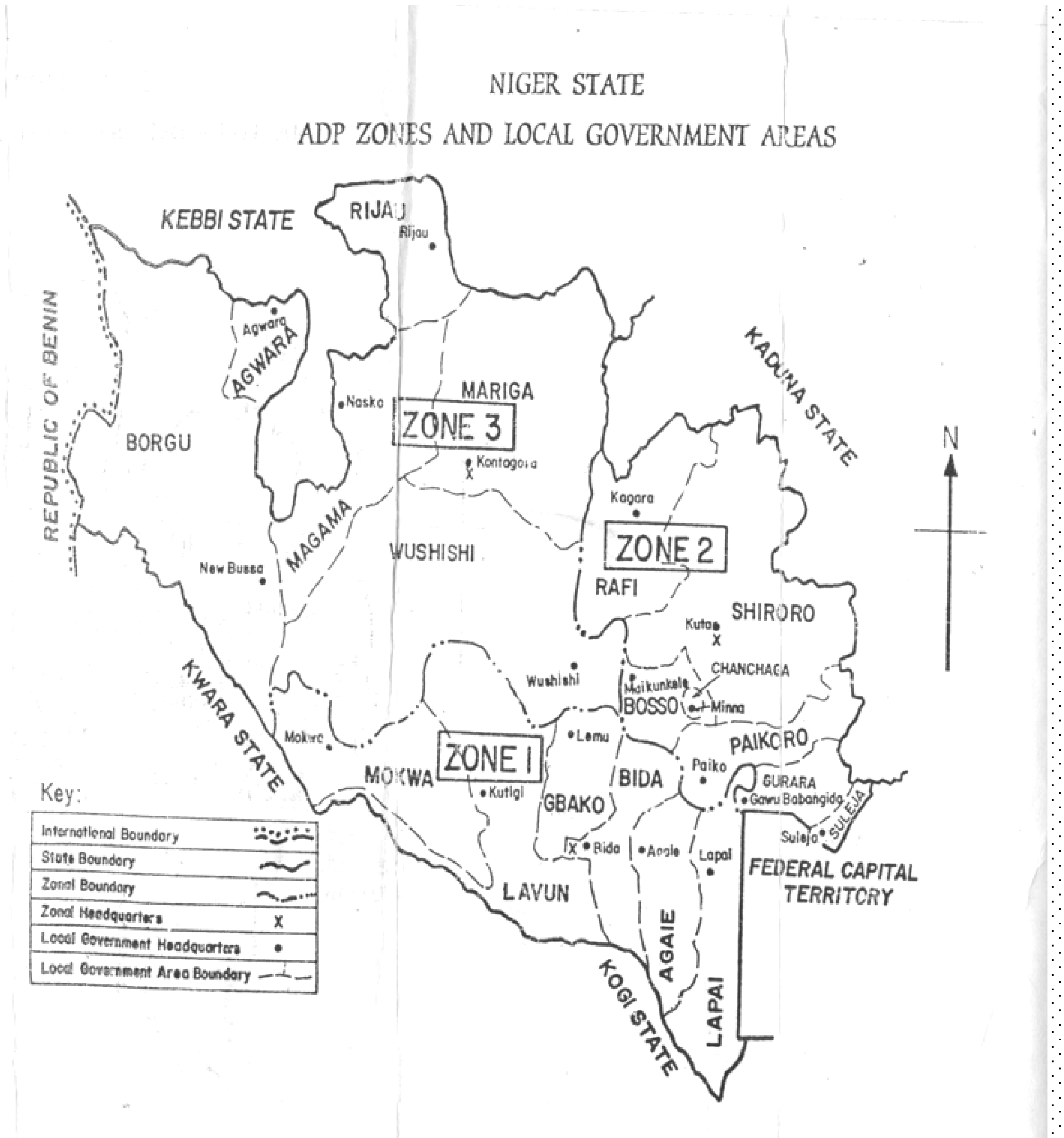

Figure 10. Map of Niger State.
Note. The map was obtained from the office of the Niger State Agricultural Development Project.

The distribution of the selected local governments across the agricultural zones was as follows: Zone 1 (Bida, Lapai, and Lavun), Zone 2 (Shiroro, Paiko, and Bosso), and Zone 3 (Wushishi, Kontagora and Mariga). On the whole, about 16 rice production circles/villages were selected from the respective local governments in which the survey was conducted in the state and from where the participants were drawn using a simple random sampling procedure and sampling frame provided by the Niger State ADP.

Sample Size

The sample size equation as proposed by Cochran (1963) was used to derive the respective sample size for each local government area selected in each state. Thus, a combination of states' sample sizes gave a representative national sample size. The sample size criteria employed in the equation were: - expected level of precision for the study, confidence level or risk level and degree of variability in attributes been measured. The level of precision also known as sampling error represented the range to which the estimated value should mirror the true mean value of the paddy rice farming population nation-wide. Generally, the confidence or risk level was based on the statistical central limit theorem and the normality assumption. The sample size equation as proposed by Cochran is written below.

$$n_0 = \frac{Z^2 pq}{e^2} \quad (54)$$

Where: n_o is the sample size, Z^2 is abscissa of normal curve for 1- α equals the desired confidence level or the alpha level (acceptable level of risk), e is the desired level of precision or the risk (margin of error) accepted in the study. The p was estimated as the proportion of the population that benefited from policy interventions and q is 1-p is the population of paddy rice farmers that did not benefit. At 10% desired level of precision, 0.05 confidence level and 0.3 variation in attribute (p) and 1-q = 0.7, Therefore, the expected risk level was 95% confidence level, implying that 95 out of every 100 samples have the true mean value of the population. Since we had a more homogenous population, maximum variability was estimated at 0.3 and 0.7, indicating the probable variation of paddy rice farmers in the selected states who benefitted from policy interventions and those who did not benefit, respectively. By this assumption it was estimated that in each state that about 30% of the entire rice farming households' population benefitted from policy interventions and 70% did not benefit.

I obtained an equal state sample size of approximately 100 rice farming households and thus, a combined sample size of 300 paddy rice farming households. In terms of the distribution of the state samples, the proportional sampling was employed, while on the average 33 participating paddy rice farmers were interviewed in each of the selected agricultural zone in respective three states, except for Kaduna State. For instance, in Kaduna State, 100 paddy rice farming households were selected and they were distributed across the three agricultural zones and the corresponding local government areas. The distribution was as follows: Maigana zone, 32 participants were selected [(Zaria LGA (10) and Sabon-Gari LGA (22)]; Birni-Gwari zone, 24 participants were selected [Kaduna South LGA (13) and Chikun LGA (11)]; and Samaru zone, 44 paddy rice farmers were selected [Kaura LGA (12); Zango-Kataf LGA (11), Jema'a LGA (11) and Kajuru LGA (10)] been the major rice producing areas in the state.

Similarly, in Nassarawa State, precisely 100 paddy rice farming households were selected in the state and were drawn from the respective agricultural zones and the associated local government areas, and rice producing circles/villages. The distribution was as follows: Southern zone, 34 participants were selected [(Obi LGA (11), Doma LGA (11) and Lafia LGA (11)]; Central zone, 33 participants were selected [Akwanga LGA (10), Wamba LGA (10), and Kokona LGA (13)]; and Western zone, 33 paddy rice farmers were selected [Nassarawa LGA (10); Keffi LGA (11) and Karu LGA (12)].

In Niger State, exactly, 100 paddy rice farming households were chosen and were drawn from the individual agricultural zones and the associated local government areas, and rice producing circles/villages. The distribution was as follows: Zone 1, 34 participants were selected [(Bida LGA (12), Lapai LGA (11) and Lavun LGA (11)]; Zone 2, 33 participants were selected [Shiroro LGA (11), Paikoro LGA (11) and Bosso LGA (11)]; and Zone 3, 33 paddy rice farmers were selected [Wushishi LGA (11); Kontagora LGA (11) and Mariga LGA (11)].

Overall, it is noted that using the sample size equation by Cochran instead of the sample size table was necessitated by the absence of exact data on the population of paddy rice farm households in each state. Specifically, it was not possible using other sample size formula, which is based on population proportion and mean since the exact population proportion and mean were also not available. What was provided by the ADPs were simply guess estimates not derived from more rigorous estimates. This study also examined similar studies based on a wider cross-section data that showed on the average, sample size ranged from 70 to 100 for a regional survey, while national surveys ranged from 240 to 1,300 (Ismail et al., 2013; Tijani, 2006).

Thus, an average sample size of 300 was considered as a good platform for the application of multiple regression procedures for estimations as employed in the study. In other words, the sample was therefore considered large enough which could provide robust and rigorous estimations of the impact of policies on the paddy rice farmers' production efficiencies.

Data Collection and Instrumentation

The survey collected two strands of data: primary and secondary data. Primary data were collected from the sampling units drawn from the respective states' sampling frames. The secondary data were obtained from the ADPs in the respective states as complementary information to the study. Data collection took place in the 3 states, 9 agricultural zones; 26 local government areas and 33 rice producing circles/villages. Data were also collected from a maximum of 100 paddy rice farm households for each state and a combine 300 paddy rice farms for the three states. Data collection also took place in a period of 8 weeks covering the selected states, thus indicating a minimum time of two weeks in each state. Thus, the survey was conducted between late July and early September, 2015. The collection of data from participating paddy rice farming households was through interviews using structured questionnaire, specifically by the researcher (see Appendix B).

However, as a result of language difficulty, the services of the respective ADPs field extension officers were employed as supporting interpreters. Most interviews were conducted in the respondent homes but in some circumstances at the farms. Each respondent was visited once. Before leaving a particular village, the completed questionnaires were further cross-checked and in cases of inconsistency and incompleteness the farmers were paid a second visit to clear all the ambiguities.

Specifically, the instrument used for the primary respondents was structured into sections. Similarly data collection from the ADPs used structured questionnaires, which were completed by the Planning and Statistics Departments in the respective states' ADPs (see Appendix C). The primary instrument was divided into five sections. Section A collected producers' socioeconomic data as follows: names of villages, local governments, agricultural zones and state. Other socioeconomic data were: age, membership of cooperative societies, land ownership status, household size, other off-income earned, farming experience, level of education attainment, means of transport and gender.

Section B collected data in terms of physical quantities and prices of farm inputs for 2014/2015 farming season as well as the paddy and milled rice output and prices for the same season. Section C solicited for data on farm management practices, which were: human resources, machinery, seed, fertilizer and chemical inputs and output management. Section D collected data on policy interventions as represented by access to: government's subsidized fertilizer, chemicals, credit, extension services, machinery hiring services, marketing facility, government's land and government's pest and weed control program. Section E asked for answers to some impressionistic questions replicating respondents' perceptions on the government rice subsector policies.

The instrument for data collection from the state ADPs was equally structured into two sections. Section A collected data on socioeconomic characteristics and political divisions of the respective states. In addition, it obtained data on the organization's budget and finances and other relevant agricultural indicators such as data on state weather conditions and production systems. Section B asked for data on the activities of the ADPs. Specifically, it collected data on fertilizer procurement and sales, farm chemical inputs distribution and management, provision of extension services, credit, pest and weed control services and the farmland allocations under the irrigation schemes, if any.

Validity and Reliability

Threats of validity could be a major impediment to the results emanating from this study. It could emanate from sampling procedures, selection of samples and instruments that were used for data collection. As in all quasi-experiment based research designs, threats to validity of results could also emanate from past experiences of the participants, which they may bring into the survey or the personal biases the researcher brings into the study during participants' selection. It could be as a result of inadequate sample size, which definitely will render the generalization invalid. Thus, to avoid these threats, participants' selections followed all the scientific steps expected in the study. In addition, appropriate sampling frames from the respective ADPs and the scientifically derived sample size were implemented.

By definition, validity of instruments refers to the degree to which the instruments used for measurement of concepts were able to capture the definitions. Two major dimensions of the threats to validity of survey instruments are identifiable - content and face validity. These examine the degree to which the various aspects of the items in the instrument captured the aspects of the concept as they were defined. To ensure face and content validity, the measurement instruments were subjected to an evaluation by at least two experts in the field of agricultural science from the Research Department of Central Bank of Nigeria. Equally, the instrument was first tested in a pilot survey that covered two participants in Nassarawa State. The pilot survey was to assess the reactions and understandings of participants before commencing the actual survey. However, the instruments were revised according to suggestions from the experts and the subsequent feedback from the pilot survey.

Another level of validity considered was the construct validity indicating the degree of conformity of the instruments with the theoretical framework definitions of the concepts measured. In line with this, the instruments were designed to identify the key variables of inputs and output of the paddy rice farming households as well as the socioeconomic characteristics and key areas of policy interventions as discussed in the literature review. Another major concern of this quasi-experiment study was the extent to which researchers and policy makers could rely on the outcomes. This is referred to as the reliability test depicting the degree of consistency. In other words, it means that we cannot get different results each time the instrument is deployed for another investigation. Therefore, to ensure reliability, the instruments applied to the study were consistently compared to the instruments used in previous empirical studies before the administration and were found to be comparable to those used in Kadiri et al. (2014), Ogundele et al. (2014), and Omondi and Shikuku (2013). Moreover, the evaluations of the instruments by experts in the discipline were of immense benefits that enhanced the reliability.

It might be necessary to point out that the information for the study was generated from the primary survey as such there were also probable measurement errors as information provided by respondents was based on *memory recall*. However, caution was exercised to check for consistency as a way of avoiding spurious responses. The problem of measurement errors was more relevant because these farmers never kept adequate records of farming activities. However, checking responses of participants was rigorously pursued with the extension field officers from the states' ADPs.

Ethical Considerations

Before proceeding to the field, all necessary permissions were obtained from the respective states' ADPs management. In addition, personal consultations were made with the Departments of Agriculture of the local government areas and the village heads, while appropriate permissions were subsequently obtained. Other actions included agreements made with the extension field officers to maintain secrecy on the identity of the respondents while interpreting the questions and the responses. Thus, questionnaire for each respondent was coded without any visible identification of the respondents to the general public. The intention was to maintain high standard of ethics and avoid disclosure since some information are personal to the respondents. The final data analysis used the individual coded numbers of respondents known to the researcher only to summarize the survey returns from the fields. Finally, the questionnaire returned after use were shredded and destroyed.

Definition of Variables

The primary data collected adequately defined the variables for data analysis. These variables were used as the database for estimating the impact of policies on technical and economic efficiency scores of a cross-section of paddy rice farmers in the three selected states in Nigeria. For instance, the estimations of technical, allocative, and economic efficiency scores used the traditional inputs and output variables as well as input and output prices. The explanations for variations on technical and economic efficiency scores of individual farm households used the policy variables defined as interventions by the Federal Government and were identified as independent variables in the case of regression-based approach. But these were controlled with farmers' socioeconomic characteristics.

Input-Output Variables

Input variables employed in this study were represented independently in both approaches (SF and DEA) for the technical efficiency estimations by X_1 to X_8 and they include: farm size in hectares, quantity of fertilizer used in kilogram, amount of rice seed planted in kilograms, quantity of herbicide used in liter, quantity of insecticide used in liter, labor in man-hour, machine use in man-hour and amount of green manure used in kilograms. In both approaches, the paddy rice output was defined as y_i and was measured in kilogram. In the case of the SF approach, a prior expectation for each of these production inputs was positive on output, meaning that output elasticity for each parameter was expected to be positive (see Table 23).

Input Prices

Input prices consisted of rent on land per hectare; price of fertilizer per kilogram, price of rice seed per kilogram, price of herbicide per kilogram, price of insecticide per kilogram, wage of labor, price of machine hired and price of green manure used per kilogram (see Table 23). A prior expectation for each input price on total cost of production was positive. This means that as input prices increase, the cost of production also increases, *ceteris paribus*, the physical quantities of inputs remained unchanged.

Table 23

List of Productive Efficiency Variables

Variables	Description/Measurement
Input Variables	
X_l=Farm size planted	Hectares harvested of Rice
X_f= Fertilizer used	Kilograms purchased
X_s=Rice Seed used	Kilograms purchased
X_h =Herbicide used	Liter of herbicides purchased
X_i =Insecticides used	Liters of insecticide purchased
X_{ll} =labor	Man-hour per cropping season
X_m=Imputed hours of machinery used	Man-hour per cropping season
X_u= Amount of green manure used	Kilograms purchased
Output Variable	
Y_i = A single paddy rice output	Physical quantity of metric tons of paddy rice output
Price Variables	Rent paid per hectare of land rented
P_l= Rent on land per hectare, if any	Measured in per kilogram
Pf=Price of fertilizer purchased	Measured in per Kilogram
Ps=Price of rice seed used	Measured in per liter
P_h =Price of herbicide Used	Measured in per liter
P_i =Price of insecticide Used	Measured per hour
P_l =Wage of labor per hour	Measured per hour
P_m=Price of machinery Used per hour	Measured in per kilogram
P_u =Price of green manure used	

Note. Compiled from information obtain from the Federal Ministry of Agriculture.

Input Costs

Based on the information on quantities of inputs and their prices, the cost of an input was derived as a product of the quantities of each input multiplied by the corresponding input price. Thus, the total cost was calculated as the sum of the costs of inputs defined as $E_i = \sum_{i=1}^{I} w_i$, where w is the input cost for an ith producer. The input costs were defined as follows: - E_i = total production cost, w_1 = cost of land, w_2 = cost of fertilizer, w_3 = cost of rice seed, w_4 = cost of herbicide, w_5 = cost of insecticide, w_6 = cost of labor, w_7 = cost of machine hired and w_8 = cost of manure.

Contextual Variables

Table 24 shows the variables used to measure all the contextual variables: - policy interventions, and socioeconomic characteristics. The policy independent variables were defined as access to: government's subsidized fertilizer, rice seeds, herbicide/ insecticide, machine hiring services, and extension services.

The socioeconomic characteristics control variables were defined as: age, membership of cooperative society, farm experience, the distance to farm; status of ownership of transport, ownership of storage facilities, and capacity of storage facilities. Thus, a prior expected impact of these variables on technical, allocative, and economic efficiency scores were indicated. While policy variables were measured by variables G_1 to G_5, and farm-specific socioeconomic characteristics were measured by variables Z_1 to Z_6 (see Table 24).

Table 24

List of Contextual Variables

Variables	Description	Expected Signs Efficiency TE	CE
Policy Variables			
G_1-Access to subsidized fertilizer	Buying govt. subsidized fertilizer	+	+
G_2-Access to subsidized rice seed	Buying govt. subsidized rice seed	+	+
G_3-Access to subsidized herbicide/insecticides	Buying govt. subsidized herbicides	+	+
G_4-Access to subsidized machine hiring services	Ability to make use of cheap hiring service	+	+
G_5-Access to extension services	Number of visits	+	N.A
Socioeconomic Factors			
Z_1=Age	The age of head of household	-	N.A
Z_2=Membership of cooperative	Active member of coop. society	+	+
Z_3=Farm experience	No. of years cultivating rice	+	+
Z_4=Distance to market	In kilometer	N.A	-
Z_5= Ownership of storage facilities	Ownership of storage facilities	+	+
Z_6 = Farm Size	Size of farm	+	+

Note. + means positive and – means negative.

Measuring Contextual Variables

The independent and control variables that were used in the regression-based models were measured at different levels: nominal, ordinal, interval, and ratio levels. The nominal level of measurement scored the statistical concepts as discrete, which is exhaustive and mutually exclusive in character. Ordinal level retained the principle of equivalence but measured by ranking or ordering by categories of the operational definitions of the concept been applied.

Table 25
Measures of Contextual Variables

Variables	Level of Measurement	Indicators
Policy Variables		
G_1-Access to subsidized fertilizer	Nominal	Access = 1, no access = 0
G_2-Access to subsidized rice seed	Nominal	Access = 1, no access = 0
G_3-Access to subsidized herbicide/insecticide	Nominal	Access = 1, no access = 0
G_4-Access to subsidized machine services	Nominal	Access = 1, no access = 0
G_6-Access to extension services	Nominal	Number of visits
Socioeconomic Factors		
Z_1=Age	Interval	Numbers of years
Z_2=Membership of cooperative	Nominal	Yes =1, No = 0
Z_3=Farm experience	Interval	Numbers of years
Z_4= Distance to Market	Interval	Numbers of Kilometers
Z_5= Ownership of storage facilities	Nominal	Yes =1, No = 0
Z_6= Farm size	Interval	Number of hectares

Note. Compiled by the Author

These were mainly categorical type of variables. Interval levels measured how precisely far apart the units were but independent of the units of measurement and they are generally, continuous variables. The ratio level showed the absolute and fixed natural zero points and similarly, it explained the independence of the units of measurement (Frankfort-Nachmias & Nachimias, 2008). Table 25 explained the basis for which the variables were measured as well as the type of questions that were asked to obtain data from the participants.

Model Specifications

The analytical frameworks were precisely two-stage modeling. Therefore, the model specifications here formalized the methods of estimations of the primary data obtained from the field survey. The model specifications were organized in blocks representing each of the selected approaches of estimations.

DEA Models

Using the DEA approach in the first stage with an input-oriented behavioral assumption for the producers, the linear programming solution for the technical efficiency for an i^{th} rice farming households was given by:

$$TE_n \min_{\lambda_i \, \theta_n} (\theta_n) \tag{55}$$

where λ_i is an N*1 vector of weights that are non-negative defining the linear combinations of the peers of the i^{th} rice farmer and θ_n is defined as the input-oriented scalar = $0<\theta_n<1$ of the TE of n rice farmers.

Thus, each farm produces a quantity of paddy rice output represented by y with multiple inputs given by x_i for ($i = x_1 \ldots x_8$). Where y is the output of paddy rice in kilograms, the inputs were defined as in Table 30. Thus, the LP problem was solved as in equation 12 using the VRS and CRS assumptions. It is usual for researchers to split the technical efficiency of producers into two portions: scale efficiency and 'pure' technical efficiency thus, the scale efficiency score of an ith farm was given as:

$$SE_t = \frac{T_{VRSt}}{T_{CRSt}} \tag{56}$$

Similarly, the nonparametric cost function was used to derive the economic efficiency scores of paddy rice farmers (see Table 27). Let x_i denote different input quantities and p_i, representing prices of different inputs, thus, the cost of each input was derived by $x_i \times p_{i.}$, The output space is a single-output space represented by y_i kilograms of paddy rice. Hence, expenditure on production was an equivalent of the sum of all input costs for 2014/2015 cropping season. The LP solution for the cost frontier using the DEA model was solved as in equation 14 and was assessed under VRS assumption only applying the input-orientation production plan of an i^{th} producer. Then the cost minimization was expressed and solved as:

$$MC_n = \min_{\lambda ix^*nj} \sum_{j=1}^{j} pnjx^*nj \tag{57}$$

In line with the theoretical construct, the estimation of allocative efficiency (AE) was derived residually from the technical and economic efficiency scores. Allocative efficiency (AE) was obtained for each of the rice farms residually as:

$$AE = \frac{EE}{TE} \tag{58}$$

SF Model Estimations

The OLS/COLS and the stochastic frontier model were used for comparable estimations of the paddy rice farms technical and economic efficiency scores in the sample states (Cullinane et al, 2006). The technical efficiency regression model under the SF approach was estimated using two assumptions of the distribution of the one-sided error term namely: the half-normal and normal-exponential distributions. The production technology was specified as a Cobb-Douglas production function. Following equation 32, the stochastic production function for the estimation of technical efficiency of rice farming households was expressed prudently in a log-linear from as:

$$\ln y_i = \beta_0 + \beta_1 \ln x_1 + \beta_2 \ln x_2 + \beta_3 \ln x_3 + \beta_4 l x_4 + \beta_5 \ln x_5 + \beta_6 \ln x_6 + \beta_7 \ln x_{7+} \beta_8 \ln x_8 + v_{i+} u_i \qquad (59)$$

The inputs remained the same as defined previously for x_1 to $x_{8,}$ while y is the paddy rice output measured in kilograms, and v_i and u_i were the decomposed error terms as u_i was attributed to the technical inefficiency term and v_i are the effects attributed to measurement errors, statistical noise and others as discussed earlier, ln is the logarithm to base. Usually, the RTS is computed as the sum of output elasticity for the various inputs and defined as $RTS = \sum \varepsilon_{qi}$. Here ε represents the output elasticity of the different inputs and the decision rule is if RTS > 1, then it is an increasing return-to-scale, RTS < 1, it is decreasing return-to-scale, and RTS = 1, it is a constant return-to-scale

The estimation of the economic efficiency scores of paddy rice farms under the SF approach used the translog cost function specification. The input prices and physical outputs were as previously defined in Table 30. The total cost and input prices were therefore normalized with the price of herbicides (p_h). Thus, the translog cost function of eight variables with the translog terms was prudently stated as:

$$\begin{aligned}
\ln\frac{E_i}{p_8} &= \beta_0 + \beta_y \ln y_i + \beta_f \ln\left(\frac{p_f}{p_h}\right)_i + \beta_s \ln\left(\frac{p_s}{p_h}\right)_i + \beta_l \ln\left(\frac{p_l}{p_h}\right)_i + \beta_m \ln\left(\frac{p_m}{p_h}\right)_i + \beta_i \ln\left(\frac{p_i}{p_h}\right)_i + \beta_u \ln\left(\frac{p_u}{p_h}\right)_i \\
&+ \frac{1}{2}\beta_{yy} \ln y_i \ln y_i + \frac{1}{2}\beta_{ff} \ln\left(\frac{p_f}{p_h}\right)_i \ln\left(\frac{p_f}{p_h}\right)_i + \frac{1}{2}\beta_{ss} \ln\left(\frac{p_s}{p_h}\right)_i \ln\left(\frac{p_s}{p_h}\right) + \frac{1}{2}\beta_{ii} \ln\left(\frac{p_i}{p_h}\right)_i \ln\left(\frac{p_i}{p_h}\right) + \frac{1}{2}\beta_{ll} \ln\left(\frac{p_l}{p_h}\right)_i \ln\left(\frac{p_l}{p_h}\right) \\
&+ \frac{1}{2}\beta_{mm} \ln\left(\frac{p_m}{p_h}\right)_i \ln\left(\frac{p_m}{p_h}\right) + \frac{1}{2}\beta_{uu} \ln\left(\frac{p_u}{p_h}\right)_i \ln\left(\frac{p_u}{p_h}\right) + \beta_{fs} \ln\ln\left(\frac{p_f}{p_h}\right)_i \ln\left(\frac{p_s}{p_h}\right)_i + \beta_{fl} \ln\ln\left(\frac{p_f}{p_h}\right)_i \ln\left(\frac{p_l}{p_h}\right)_i + \beta_{fm} \ln\ln\left(\frac{p_f}{p_h}\right)_i \ln\left(\frac{p_m}{p_h}\right)_i \\
&+ \beta_{fi} \ln\ln\left(\frac{p_f}{p_h}\right)_i \ln\left(\frac{p_i}{p_h}\right)_i + \beta_{fu} \ln\ln\left(\frac{p_f}{p_h}\right)_i \ln\left(\frac{p_u}{p_h}\right)_i + \beta_{sl} \ln\left(\frac{p_s}{p_h}\right)_i \ln\left(\frac{p_l}{p_h}\right)_i + \beta_{sm} \ln\left(\frac{p_s}{p_h}\right)_i \ln\left(\frac{p_m}{p_h}\right)_i + \beta_{si} \ln\left(\frac{p_s}{p_h}\right)_i \ln\left(\frac{p_i}{p_h}\right)_i \\
&+ \beta_{su} \ln\ln\left(\frac{p_s}{p_h}\right)_i \ln\left(\frac{p_u}{p_h}\right)_i + \beta_{lm} \ln\left(\frac{p_l}{p_h}\right)_i \ln\left(\frac{p_m}{p_h}\right)_i + \beta_{li} \ln\left(\frac{p_l}{p_h}\right)_i \ln\left(\frac{p_i}{p_h}\right)_i + \beta_{lu} \ln\left(\frac{p_l}{p_h}\right)_i \ln\left(\frac{p_u}{p_h}\right)_i + \beta_{mi} \ln\left(\frac{p_m}{p_h}\right)_i \ln\left(\frac{p_i}{p_h}\right)_i \\
&+ \beta_{mu} \ln\left(\frac{p_m}{p_h}\right)_i \ln\left(\frac{p_u}{p_h}\right)_i \qquad (60)
\end{aligned}$$

Here the prices remained as defined in Table 30, while y_i is the paddy rice output measured in kilograms for the i^{th} rice producer, assuming that the composite error term is comprised of u_i and v_i. The β parameters to be estimated include the elasticities of substitution of inputs, own price elasticities and cross price elasticities. However, the cost function was estimated using only the normal half-normal distribution assumption of the one-sided error term.

Second Stage Estimations

In the second stage, the estimations of the impact of policies on the technical and cost efficiency scores used the generated estimates of technical and cost efficiency scores of individual paddy rice farm households and applied the fractional logistic models with the independent variables. The policy variables were classified as independent variable, while the possible effects of policy variables were controlled using the socioeconomic characteristics specific to paddy rice farms. This was to account for variations on rice farmer's technical and cost efficiency scores. Thus, the fractional logistic regression models for technical and cost efficiency scores were expressed in general form as:

$$y^* = \log\left(\frac{y_i}{1-y_i}\right) = \theta_0 + \sum_{n=1}^{5} \theta_n g_{ni} + \sum_{k=1}^{7} \theta_k z_{ki} + \varepsilon_i \qquad (61)$$

All variables remained the same as defined in Table 24. Where θ_0, θ_n and θ_k were the parameters that were estimated, g_{ni} represents the vector of independent policy variables and z_{ki} represents vector of control variables for farm i and ε_i is the error term, which was defined as independently and normally distributed. Therefore, it was defined to have zero mean and constant variance σ^2. The policy variables were defined as

g_1 to g_5 and socioeconomic control variables were defined as z_1 to z_6.

Conclusion

The chapter gave a detailed explanation of the methodological approaches explored in the study. Essentially, it discussed the research design, sampling strategy, sample size, data collection and instrumentation, actions taken to achieve validity and reliability of results and outcomes, ethical considerations, definition of variables and the model specifications. In this context, the study engaged mixtures of sampling techniques, estimation methods such as proportional sampling, stratified random sampling, cluster sampling and simple random sampling to obtain participants from the three selected states namely Kaduna, Nassarawa and Niger States.

The aim of the study was to evaluate the technical, allocative and economic efficiency levels of paddy rice farmers and the impact of policies on possible variations in the scores across the paddy rice farm households in Nigeria, using three selected states. The Cochran sample size formula was used to determine the sample size employed for the collection of primary data. Thus data was collected from a total of 300 paddy rice farmers in the three selected states. Data were obtained from 100 participants each from the three states using a structured questionnaire and interview technique. The collection of data came from samples drawn from 26 local government areas in the states as well as from 33 rice producing circles/villages.

The data collection survey was conducted in the three states for a period of 8 weeks lasting from late July to early September, indicating an average of two weeks in each state. Adequate steps were taken to ensure validity of results and the reliability. As such, the survey structured instrument was subjected to expert opinions and it was also tested in a pilot survey conducted in Nassarawa state using only two participants. Subsequently, the structured survey instrument was revised based on feedbacks from the experts and the pilot survey before the commencement of the survey. Furthermore, the concepts measured were subjected to an evaluation to ensure that they were in conformity as suggested by the theoretical and empirical literature. Before the commencement of the survey in each state adequate permissions were obtained through consultations at all levels of governments and the agencies, while the identity of the participants were concealed using number codes for identification.

The chapter further highlighted the definitions of the variables, the measurement levels as well as identified the approaches of estimations. Basically, the definition of the variables identified the traditional efficiency variables of inputs and output. In this case the estimations covered multiple inputs with single output production space. Invariably, to determine the possible cause of variations in respective scores by the participants, the contextual variables were defined. In this light, the contextual variables were defined in two groups. The first group generally defined five policy independent variables as the main variables of interest. However, the second group defined about six socioeconomic characteristics specific to each rice farm households as control variables to the effects of policy variables, accounting for variations in efficiency scores across the paddy rice farms.

Overall, the models estimated were specified, thus revealing the application of multiple estimating approaches namely the DEA and the SF techniques. However, the assessment of the impact of policies at the second stage used the more reliable estimates of technical and cost efficiency individual farm score. First was the estimation of the respective efficiency scores, using the traditional efficiency inputs and single paddy rice output. In the second stage, the efficiency scores were subjected to regression-based estimation using the contextual variables as predictor variables and the efficiency scores as the dependent variables. The study employed fractional logistic models for the estimation of the impact of policies on technical and cost efficiency scores of the rice farm households in the sample.

The remainder of the study reports the analysis of the empirical data and estimation results as well as the discussions and interpretations of the findings of the study, conclusions, implications for public policy and social change, and recommendations. Chapter 4 presents the empirical results of the field study, explaining the summary statistics of data obtained from the paddy rice farmers in the surveyed states. The chapter also discusses the profitability analysis of rice production in the respective states. Finally, the estimations of the efficiency frontiers for the technical, allocative and economic efficiency measures using the DEA and the SF approaches are discussed.

Chapter 4: Analysis of Data

Introduction

The chapter presents the analysis of results for the empirical data obtained from this study's field survey of paddy rice farming households in Nigeria. It is structured into five sections. Section 1 highlights the data analytical framework employed to evaluate the primary data obtained from the field survey. It also explains the procedures of analysis of the data, indicating the multiple steps employed to evaluate the data. In Section 2, an analysis of the summary statistics of data collected is discussed, explaining the major characteristics of the paddy rice farms households, farmers and farm management practices in the three states. The relevant statistical tests such as descriptive statistic and ANOVA are applied to explain the data.

Similarly, Section 3 provides an analysis of the profitability of paddy rice cultivation business in the three states, while specific tests used to further enhance the validity of the results and findings from the analysis are examined. Section 4 focuses on the main interest of this study: the estimations of the technical, allocative, and economic efficiency scores of paddy rice farm households, using the pooled data obtained from the field survey. Subsequently, some statistical tests such as parametric Independent Analysis of Variance (ANOVA), nonparametric Kruskal-Wallis and log-likelihood ratio tests are applied to evaluate the validity and reliability of the results of the estimations in terms of comparing the mean technical and cost efficiency across the three states samples.

Data Analytical Framework

Data analysis was organized at two different levels namely the consolidated data including all the data returned from all the states (metadata) and at the state levels (state data). The consolidated data set covered all field data returned from all the respondent paddy rice farmers, irrespective of the state samples. The state data only covered the data set at individual state levels. Figure 11 shows the analytical framework used in the study, including the three levels of analysis: descriptive analysis, profitability analysis of paddy rice cultivation business in Nigeria, and efficiency analysis of the paddy rice farm households in the sampled states.

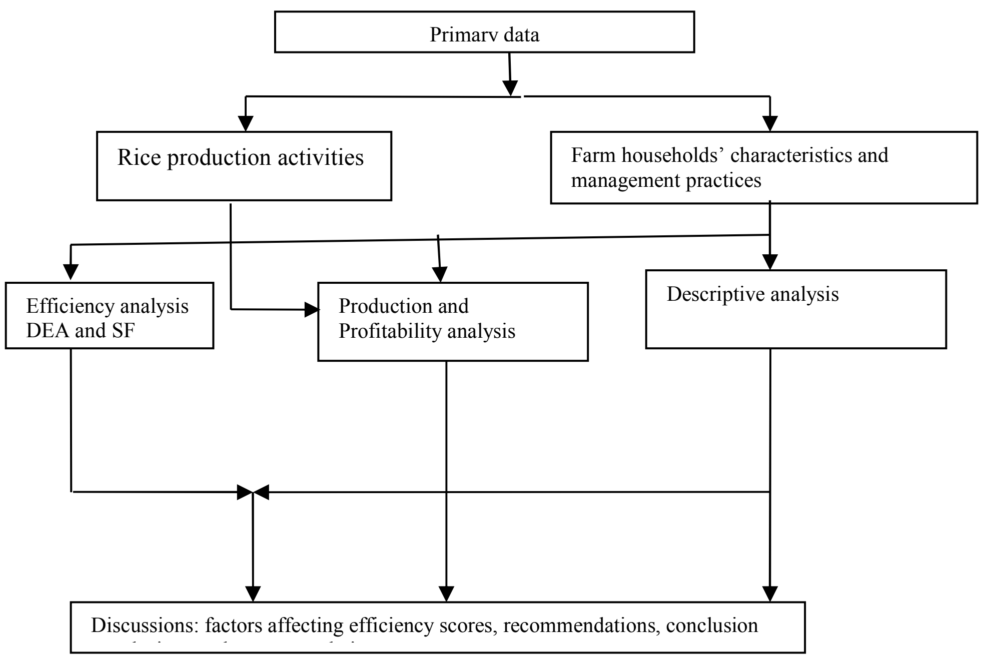

Figure 11. A diagram of the data analytical framework.

Overall, four primary data sets were used during the data presentations for the three scopes of analysis. The descriptive statistic explained the key farm households and farmers' characteristics, resources management practices and production activities of paddy rice farm households and these were analyzed using the four different data sets. The first data set consisted of the consolidated returns describing the paddy rice farm households and farmers' characteristics, resources management practices and production activities, using the metadata. The other three data sets were the consolidated returns along the state samples; these data sets represented Kaduna, Nassarawa and Niger States, respectively. The statedata set individually explained the specific farm households, farmers' characteristics and resources management practices and production activities associated with paddy rice farmers in their respective states. Similarly, the primary data on production activities collected from the paddy rice farms were employed to conduct profitability analysis of paddy rice cultivation business in Nigeria. Accordingly, the analysis was performed using the combined dataset as well as the datasets of the three individual states.

The profitability analysis of paddy rice cultivation was analyzed using these four distinct datasets. In the same vein, the production dataset obtained from the fieldwork in sampled states were explored at the same four levels to estimate the technical, allocative and economic as well as the scale efficiency scores of the rice farm households (see Table 24). The key statistics discussed under the descriptive analysis were the central tendency statistic (mean), standard deviation, maximum and minimum (Field, 2009). The profitability analysis assessed the cost of inputs and the revenue from the sale of paddy rice output. The estimation of the technical, allocative, and economic efficiency scores applied two independent models, the DEA and SF models.

These multiple steps were justified because of major differences between the state governments field data. Field data indicated that there were major differences in the datasets from the three states as a result of differences in the intensity of the implementation of rice subsector policies and the rice production technologies available in each state. Using these four datasets independently was thus necessary in order to account for the peculiar characteristics of the states as a result of differences in resource endowments. Thus, implementing these multiple steps of analysis accounted for each state's peculiar characteristics.

The consolidated data set was defined as the unrestricted technology for the rice production system. The use of multiple procedures was intended to verify whether or not there were significant variations in technical, allocative, and economic efficiency scores, or in the socioeconomic characteristics and production activities of paddy rice farms in the selected states. Parametric and nonparametric tests were conducted at all steps and for all approaches. This testing was designed to ensure that the results met specific statistical standards for the purpose of validity and reliability of results, as well as to assess the generalizability of the findings to the whole rice-producing population across Nigeria. Thus, parametric and nonparametric tests were explored for the descriptive analysis, profitability analysis and the efficiency estimations.

The tests were aimed at explaining whether they were statistical differences between the farm households and farmer characteristics, and management practices, profitability levels and the mean efficiency scores from the data obtained during fieldwork. In order words, the tests were to determine whether the different samples from the three selected states where surveys were conducted are from the same population. Thus, the hypothesis was stated as:

$$H_0 \sim \mu_1 = \mu_2 = \mu_3, \text{ for } \mu_1 - \mu_2 - \mu_3 = 0 \qquad (62)$$

$$H_1 \sim \mu_1 \neq \mu_2 \neq \mu_3 \text{ for } \mu_1 - \mu_2 - \mu_3 \neq 0$$

Parametric tests were, however, used in the analysis of farm and farmer characteristics, and management practices, profitability of business and mean efficiency scores using the SF estimated efficiency scores of paddy rice farmers from the three groups namely, Kaduna, Nassarawa, and Niger States. Since there were more than two independent groups, the parametric independent *t* test was less appropriate. On this note, the appropriate test used given the three independent groups was the Independent Analysis of Variance (Independent ANOVA) based on the assumption of a single factor. Thus, the ANOVA test focused on explaining whether the three independent groups for the defined variables were the same. Accordingly, the null hypothesis was defined as the means of the samples for instance, mean efficiency scores were equal. Alternative hypothesis stated that the means were not equal.

Usually, the ANOVA produces the *F* statistics or the *F* ratio, which is similar to the *t*-statistics. Thus, in this study the *F* ratio explains the amount of systematic variance in the primary data obtained to an amount of the unsystematic variance in the same data.

Overall, it is an omnibus test that shows the ratio of the model to its error. Therefore, the value of *F* statistics produced was applied to test whether there were significant differences in the sample mean of defined variables.

On the contrary, in the DEA approach, nonparametric diagnostic tests of results were carried out to determine whether there were statistical differences in the efficiency scores of paddy rice farms across the three samples. Since, the statistical distributions of efficiency scores in a DEA estimation approach is unknown, the appropriate test was therefore, the nonparametric tests. Similar to the parametric test, the rank-sum test developed by Wilcoxon-Mann-Whitney was less appropriate because we have more than two independent groups (Kaduna, Nassarawa and Niger States). Essentially, like the ANOVA technique, the more appropriate test employed was Kruskal-Wallis rank nonparametric test.

The Kruskal-Wallis rank test is based on ranked data, which uses the test statistic *H*. The *H* test statistic has a chi-square distribution, while for the distribution there is only one value for the degrees of freedom, which is one less than the number of groups denoted as $k-1$. Kruskal-Wallis rank test identifies the independence of data from different samples or groups, which was used to identify whether there were significant statistical differences in the levels of technical, allocative and economic efficiency scores of paddy rice farmers across the selected states.

The study also used the appropriate parametric tests under the SF approach using the maximum likelihood procedure. The test applied was the classical test of log-likelihood ratio, which is defined as:

$$LR = -2\left[L(\theta_0) - L(\hat{\theta})\right] = 2\left[L(\hat{\theta}) - L(\theta_0)\right] \qquad (63)$$

This is asymptotically distributed as χ^2 random variables, and degrees of freedom equal to the number of hypotheses.

The primary data were initially organized after the fieldwork with an Excel spreadsheet. Subsequently, the software was used to conduct the primary tests and generate the summary statistics of the relevant variables. The estimations of the technical and cost efficiency scores under the DEA approach used the PIM-DEA Version 3.2 computer software program. On the other hand, the estimations of technical and economic efficiency scores in SF model and other regression-based estimations employed the STATA Version 14.1 computer software.

Empirical Findings from the Field Study

The section is divided into three main subsections, which include discussions on the descriptive analysis, profitability analysis of paddy rice cultivation business, and the efficiency analysis of paddy rice farms in Nigeria.

Descriptive Analysis

Descriptive statistics of farm households revealed the relevant characteristics of rice farm households, the farmers, farm resources management practices, rice farming information and the production activities are presented in this subsection.

Paddy rice farm household characteristics

The discussions focused on the nature of the paddy rice cultivation business, the main occupation of respondents, membership of cooperative organizations and farming objectives; land resources, production system, farm size and land tenure system; labor resources, farm assets, and farm credit and the debt of participating paddy rice farm households from the sampled states.

Nature of paddy rice cultivation business. Understanding farm organization requires a blending of the modern theory of the firm with the seasonal nature of agricultural production. Seasonality thus distinguishes farm organizations from industrial organizations. However, in many industrial countries, the nature of organization of agricultural businesses is maturing from mere sole proprietorship to large-scale agricultural corporations known as commercial agriculture (Allen & Lueck, 1998). Like any other business organization, rice farm businesses are also organized as either: sole proprietorship, partnership or as a corporation.

In the case of the sampled states, evidences that emerged from the fieldwork showed that the respondents were 100.0% sole proprietorship of their farms. Thus, the head of the households managed the farms on a daily basis and was generally, responsible for the success of the farm in terms of return on investment and profit. They were also responsible for the failure of the business and the poor performances of their respective farms. In this regard, day-to-day production, marketing and consumption decisions were made by the heads of the households.

Main occupation and membership of cooperative organizations. In terms of main farming activity, the empirical findings suggested that rice cultivation was the main occupation of majority of sample households as well as the major important activity amongst all daily activities. Table 26 showed approximately that 99.7% of the sample rice farm households reported paddy rice farming as a major occupation, while only 0.3% was engaged in forestry alongside paddy rice cultivation. This showed that rice cultivation was a major way of life in the study states.

Table 26
Characteristics of Rice Farm Households in Selected States in Nigeria

Items	Kaduna (*n*=100)	Nassarawa (*n*=100)	Niger (*n*=100)	Total (*N*=300)
Main Occupation (%)				
Rice farming	99.0	100.0	100.0	99.7
Tree plantation	1.0	0.0	0.0	0.3
Off- farm activity	0.0	0.0	0.0	0.0
Total	100.0	100.0	100.0	100.0
Objective of rice farming (%)				
Commercial	37.0	28.0	37.0	34.0
Semi-commercial	63.0	72.0	63.0	66.0
Subsistence	0.0	0.0	0.0	0.0
Total	100.0	100.0	100.0	100.0
Membership of cooperative society (%)				
Membership	55.0	16.0	33.0	34.7
Non-Membership	45.0	84.0	67.0	65.3
Total	100.0	100.0	100.0	100.0

Note. Compiled from field study data.

Consequently, the key objective of paddy rice production in the sampled states was described as semi commercial as an average of 66.0% of the respondents reported producing paddy rice to provide enough for consumption by members of households and sell the surplus amount in the local market. However, about 34.0% of paddy rice farmers were involved in paddy rice production mainly for commercial purpose. Hence, the latter group was found not involved in the milling and processing of paddy rice output into milled rice for consumption. The former was largely engaged in milling the paddy rice output for home consumption and disposal of the surplus amount in the local market.

Further investigation revealed that the farming households consumed an average of 12.0% of the total milled rice, while 88.0% was disposed at the local market. There were remarkable differences in percentage of farmers that reported semi commercial objective in Nassarawa state, compared to the other states. The percentage of the respondent paddy rice farmers that reported semi commercial objective in the state stood at 72.0%.

Precisely, about 34.7% of the respondent paddy rice farm households for all samples reported membership of cooperative societies, while 65.7% reported not belonging to any cooperative society. Of the 104 paddy rice farmers that reported been a member of cooperative society, 103 of the farmers were members of farmers' cooperative societies, while one belonged to consumer cooperative society. Memberships of farmers' cooperative societies were more important in Kaduna State as more than half reported memberships of cooperative societies but 45.0% were found not belonging to any of the cooperative society. The least was Nassarawa State as only 16.0% of the interviewed farmers belonged to cooperative societies mainly farmers' cooperative societies, while 84.0% were not members of any cooperative society (see Table 26).

Land resources. The paddy rice farmers in the sampled states were largely small holders (see Table 27). The average paddy rice farm size (land per farm) was 2.26 ha, which was lower than the average farm size of 3 ha for Nigeria (Apata, Folayan, Apata, & Akinlua (2011). The median farm size was 2 ha thus, confirming the finding that majority of the Nigerian paddy rice farms were operating with small rice farms (Ayinde, Ojehomon, Daramola & Falaki, 2013). On a consolidated basis, the paddy rice farms in the states ranged from 0.5 ha to 10.0 ha per farm. Nevertheless, the average farm size was considered moderate when compared to average farm size of 0.6 ha in China (Adamopoulos & Restuccia, 2011).

A disaggregated data on farm size showed that average paddy rice farm size was highest in Kaduna State measured in hectares (M=2.62, SD = 2.08), while the lowest was in Niger State (M = 1.99, SD = 1.44). The average farm size for Nassarawa paddy rice farmers was 2.16 ha. Further results using the F-ratio test statistic showed that there were statistically significant differences in average farm size across the three states for F (2,297) = 3.33; p < 05.

About 94.7% of the paddy rice farm households in the sampled states were largely holding one plot, while only a small proportion of 5.3% of the total were reported holding two plots. The paddy rice cultivation activities in the states were predominately lowland cultivation system accounting for an approximately 91.3% of the total farm size, while the upland paddy rice cultivation system mainly in Kaduna state, accounted for the balance. In terms of scale of farm operations, about 70.0% of the paddy rice farms were reported cultivating between 0.5ha and 2ha and were classified as small-scale farms. Similarly, 26.3% (3 to 5 ha) and 3.7% (6 ha and above) of the paddy rice farms were classified as medium- and large-scale farming operations, respectively (see Table 27).

Table 27
Land Resources of Paddy Rice Farm Households in Selected States in Nigeria

Items	Kaduna (*n*=100)	Nassarawa (*n*=100)	Niger (*n*=100)	Total (*N*=300)
Farm size (ha)				
Mean	2.62	2.16	1.99	2.26
F statistic		3.33**		
Standard deviation	2.08	1.79	1.44	1.80
Minimum	0.50	0.50	0.50	0.50
Maximum	10.00	10.00	10.00	10.00
Farm scale (%)				
Small (0.5 to 2 ha)	61.0	74.0	75.0	70.0
Medium (3 to 5 ha)	31.0	24.0	24.0	26.3
Large (6 ha and above)	8.0	2.0	1.0	3.7
Productions System (%)				
Upland	25.0	0.0	1	8.7
Lowland	75.0	100.0	99	91.3
Irrigation	0.0	0.0	0	0.0
Number of Plots (%)				
One	87.0	98.0	99.0	94.7
Two	13.0	2.0	1.0	5.3
Three and above	0.0	0.0	0.0	0.0
Average Yield per Hectare (metric tons)				
Mean	3.29	1.75	2.16	2.40
F statistic		81.44*		
Standard deviation	1.21	0.54	0.76	1.09
Minimum	1.00	1.00	1.00	1.00
Maximum	7.00	4.00	4.50	7.00

Notes. Compiled from field survey data. * is significance level at 1% and ** at 5%.

Finally, the average estimated yield per hectare of paddy rice for all samples was 2.90 metric tons per hectare of paddy rice farm land. This average yield was above the estimated national average of 2.5 metric tons per hectare but far below the world average yield of 4.1 metric tons per hectare (IRRI, 2013). The median and the mode estimated yield were the same at 2.0 metric tons per hectare, indicating a normal distribution of the yield. The average yield per hectare however ranged between 1 metric ton and 7 metric tons, also showing a great dispersion in yield among the paddy rice farmers. The dispersion was explained largely, by differences in technology gaps as well as in the intensity in the implementation of the rice subsector policies across the states (see Table 27).

For instance, in Kaduna State, the average yield estimated was 3.29 metric tons per hectare, which was above the national average and very close to the global average, while in Nassarawa and Niger States, the estimated average yields per hectare were 1.75 and 2.16 metric tons per hectare, respectively, and were below the national average. The yield per hectare of paddy rice output ranged between 1 metric ton and 7 metric tons per hectare in Kaduna State. Contrastingly, the estimated yield per hectare of paddy rice output ranged between 1 metric ton and 4.0 metric tons per hectare in Nassarawa, while it ranged between 1 metric ton and 4.5 metric tons per hectare in Niger. The ANOVA estimation result confirmed that there were statistically significant differences in estimated average farm yield across the three samples for F (2,297) = 81.44; $p < 001$.

Land tenure system. The relevance of land tenure system in agriculture efficiency is well documented. Land tenure system is believed to determine the quantum of rights, kinds and nature of access that the farmer may have and consequently the way he/she uses the land to promote the well being of the household. In essence, land tenure refers to the right on land and the resources in it and the economic effects are related to the improved access to institutional credit, improved investments in agricultural land, higher productivity, and higher farm output and rural incomes (Michler & Shively, 2015).

Table 28 confirmed that about 69.3% of the respondent paddy rice farms were situated on owned land that is by means of traditional inheritance. Similarly, about 17.3% of the farms were situated in rented land and subsequently attracts rent, which has implication on the cost of production. On the whole, about 13.0% benefitted from government owned managed agricultural land allocations by the ADPs.

Specifically, the results were similar in Nassarawa and Niger States but differed substantially in Kaduna State. For example, in Kaduna State, about 49.0% of the paddy rice farms were situated in owned land, while about 34% were located in Kaduna State ADP managed agricultural land. In most instances, the farmers were asked to pay little token and they also benefitted immensely from the services of government agricultural mechanization services. The results from the fieldwork also exposed that the average number of years in which the paddy rice farmlands were cultivated by respondents was 9.18 years. The ANOVA estimation at $F\ (2,297) = 0.53$; $p = 0.59$ showed that the differences in means were not statistically significant thus implying that the mean years of land use for all the three states were statistically equal.

Table 28

Land Tenancy of Paddy Rice Farm Households in Selected States in Nigeria

Items	Kaduna (n=100)	Nassarawa (n=100)	Niger (n=100)	Total (N=300)
Land tenancy (%)				
By traditional inheritance	49.0	85.0	74.0	69.3
Rented	17.0	15.0	20.0	17.3
Communal (Gift Tenure System)	0.0	0.0	1.0	0.3
Government	34.0	0.0	5.0	13.0
Distance from home to paddy rice farm (km)				
Mean	5.52	5.54	7.65	6.24
F statistic		7.33*		
Standard deviation	5.80	4.13	3.25	4.26
Minimum	1.00	1.00	2.00	1.00
Maximum	45.00	20.00	15.00	45.00
Land Use Year (Years)				
Mean	8.68	9.25	9.62	9.18
F statistic		0.53^{ns}		
Standard deviation	5.95	6.50	7.03	6.50
Minimum	1.00	1.00	1.00	1.00
Maximum	30.00	31.00	30.00	31.00

Notes. Compiled from field survey data. * is significance level at 1%, ** at 5%, *** at 10%, and *ns* means not statistically significant.

A further evaluation of one of the characteristics of rice farm households revealed that the distance from home to the paddy rice farm plots was a moderate distance. The average distance was 6.24 km, which suggested that the farms were not too far away from their homes. However, the average distance recorded for each of the sampled states showed substantial differences. As such the ANOVA test results of F (2,297) = 7.33; p <

001 explained that there was statistically significant differences in sample means in terms of distance to farms (see Table 28).

Labor resources. This section discussed generally the family size of rice farm households as well as the contributions of family labor input to rice production activities. The types of labor used in agricultural production in Africa can be broadly classified into three categories: family labor, labor exchange and hired labor. In the literature, it is established that family labor constituted about 50% of total labor input in agricultural production. The significant contributions of family labor in agricultural production means that family labor is a contributor to higher productivity in the absence of intensive application of farm mechanization.

Moreover, most of the paddy rice producers in the continent are described as poor and lack access to institutional credit and naturally will rely heavily on the family labor. Thus, the amount of family labor in rural agricultural production is determined by the family size (Takane, 2008). The available family labor is constituted by women and children and this has been the major factor driving the rural population. It is established that women and children contribute about 50% of agriculture workforce in Africa (FAO, 2011). In consideration of the importance of family labor to the labor intensive paddy rice cultivation, the rice farm households were asked to identify the family size, the number of family labor, the imputed wage on family labor per day and the distribution of family labor use by age and sex.

Table 29 revealed that on the average about 66.7% of the rice farm households employed the services of family labor, constituting their wives and children, while only about 33.3% of the farms did not make use of family labor. Specifically, Nassarawa was outstanding as about 70.0% of the paddy rice farm households employed the service of their families in paddy rice cultivation. The result thus, confirmed that the use of family labor was the norm and a major input in rice cultivation.

Table 29

Family Labor Resources of Paddy Rice Farm Households

Items	Kaduna (*n*=100)	Nassarawa (*n*=100)	Niger (*n*=100)	Total (*N*=300)
Use of Family Labor (%)				
Use of Family labor	63.0	70.0	67.0	66.7
Do not use Family Labor	37.0	30.0	33.0	33.3
Total	100.0	100.0	100.0	100.0
Family Size (No. of Members)				
Mean	9.4	9.1	9.7	9.4
F statistic		0.32^{ns}		
Standard deviation	5.4	5.5	4.9	5.3
Minimum	1.0	2.0	2.0	1.0
Maximum	25.0	35.0	24.0	35.0

Note. Compiled from field survey data. The symbol *ns* means not statistically significant.

The importance of family labor in paddy rice production is supported by the large family size of our sample rice farm households. The average family size was approximately 9.4 persons, which was relatively higher than the sub-Saharan Africa average family size of 5.6 persons and average family size of paddy rice farm households of 2.5 persons per household in China. However, this was relatively close to the average family size of 10.1 persons for the rice producing households in Ghana (van de Berg et al., 2005; Wiredu et al., 2014). Nevertheless, the results showed no statistically significant differences in average family size across the three state samples as $F(2,297) = 0.32$; $p = 0.723$.

Table 30
Imputed Daily and Total Wage Bill of Family Labor Employed

Items	Kaduna (*n*=100)	Nassarawa (*n*=100)	Niger (*n*=100)	Total (*N*=300)
Imputed Family Labor Wage (Naira/per day)				
Mean	321.0	271.0	158.0	250.0
F statistic		13.84*		
Standard deviation	288.9	212.6	149.9	233.9
Minimum	0.0	0.0	0.0	0.0
Maximum	1000.0	800.0	700.0	1000.0
Total Imputed Family Labor Wage (Naira)				
Mean	12140.0	13195.5	5058.0	10131.2
F statistic		6.92*		
Standard deviation	16802.0	22783.7	6890.4	17151.3
Minimum	0.0	0.0	0.0	0.0
Maximum	88000.0	130500.0	33600.0	130500.0

Notes. Compiled from field survey data. * is significance level at 1%.

Table 30 discussed the daily and total wage imputed by respondents that were due to family members who worked in the respective paddy rice farms. An average daily wage imputed for family members who worked at the rice farms was ₦250.0, implying that average imputed wage for a cropping season per paddy rice farm was ₦10, 131.2.

Furthermore, the results confirmed that there were statistically significant differences across the state samples. Thus, at F (2,297) = 13.84; p < 0.001 and F (2,297) = 6.92; p < 0.001, the test indicated that the mean of the independent state samples for the daily wage and average total wage bill of family labor were not equal, respectively.

Farm assets. The farm assets were valued using the purchase value less the accumulated depreciation. The major farm assets considered were: farm tractors, water pumping machine, water hose and sprayers. Consequently, the farm tractor was assumed to have an estimated life span of 20 years, while the water pumping machine, water hose and sprayer were assumed to have 5, 3 and 10 years estimated life span, respectively. A straight-line method of depreciation by assuming a zero salvage value was applied for each farm asset.

Hence, information on ownership of farm assets was obtained from the respondents by asking questions related to farm mechanization. The questions were: ownership of identified farm assets, year and cost of purchase and number owned. The results of the survey indicated that ownership of important farm assets for rice cultivation was low in all the samples. For instance, only 1.7% of the respondent farm households reported owning farm tractors and sprayers, while only 1% owned water pumping machine as no one reported owing water hose. The average total value of farm assets as reported by the few owners amounted to ₦2, 444.5 thousand and was approximately USD12, 408. 6 per paddy rice farm. This consisted of tractors (₦2, 411.8 thousand); water pumping machines (₦25.2 thousand) and sprayers (₦7.5 thousand). Ownership of farm assets was more relevant in Kaduna State but was completely absent in Nassarawa State (see Table 31).

Table 31

Ownership and Value of Owned Farm Assets by Paddy Rice Farm Households

Items	Kaduna (*n*=100)	Nassarawa (*n*=100)	Niger (*n*=100)	Total (*N*=300)
Ownership of farm assets (%)				
Tractors	4.0	0.0	1.0	1.7
Pumping machines	2.0	0.0	1.0	1.0
Water hose	0.0	0.0	0.0	0.0
Sprayers	5.0	0.0	0.0	1.7
Value of owned farm assets (000'Naira/farm)				
Tractors	2,375.0	0.0	2,800.0	2,411.8
Pumping machines	1.8	0.0	7.2	25.2
Water hose	0.0	0.0	0.0	0.0
Sprayers	7.7	0.0	0.0	7.5
Total value of farm assets	2,384.5	0.0	2,807.2	2,444.5

Note. Compiled from field survey data.

Farm credits and debts. Credit is described as an important engine in paddy rice cultivation. According to Obansa and Maduekwe (2013), finance is the sole of paddy rice cultivation business and it represents a long-term financing that could induce growth in rice output and paddy rice farm productive efficiency. Farm loans obtained by paddy rice farm households were used to purchase farm inputs and as such generated debt and interest expense. Accordingly, the households were asked to indicate whether they have access to loans, the amount, the source, interest rate, duration and the interest expense.

The results of the survey uncovered that only 4.0% of the farm households were able to obtain credits at an approximately average interest rate of 7.6%. While credits were available to exactly 9.0% and 3.0% of the paddy rice farmers in Kaduna and Niger States, respectively and none of the respondents received any credit in Nassarawa State. The average amount of credit for those who received credit was ₦105, 000.0, while the most important sources of credit were state and local governments as well as friends and relations, accounting for 45.5%, 27.3% and 18.2% of the total credits, respectively (see Table 32).

Table 32

Farm Credits and Debt of Paddy Rice Farm Households

Items	Kaduna (*n*=100)	Nassarawa (*n*=100)	Niger (*n*=100)	Total (*N*=300)
Access to Credit (%)				
Access to credit	9.0	0.0	3.0	4.0
No-access to credit	91.0	100.0	97.0	96.0
Source of credit (%)				
Friends/Relations	0.0	0.0	66.7	18.2
Community Bank	0.0	0.0	0.0	0.0
Nigeria Agricultural Bank	12.5	0.0	0.0	9.1
Deposit Money Banks	0.0	0.0	0.0	0.0
ACGSF	0.0	0.0	0.0	0.0
State Governments	62.5	0.0	0.0	45.5
Local Governments	25.0	0.0	33.3	27.3
Amount of credit (000'Naira/farm)	93.3	0.0	140.0	105
Average interest rate (%)	9.6	0.0	0.0	7.2

Notes: Compiled from field survey data. ACGSF represents the acronym for the special agricultural financing by the Central Bank of Nigeria and the Federal Government.

During the survey, the interviewer sought for the reasons why the farmers were unable to have access to credit from any of the sources. The results showed that more than half of the respondents expressed difficulty to access credits as a major reason for not been able to obtain credit. Others sighted nonavailability of credit locally as a major reason, while only about marginal number expressed the reason of high cost of borrowing as a major hindrance.

Farmers' Characteristics

Farm management is a science and an art employed by farmers to optimize the use of resources in their farms with the aim of achieving farm objectives of higher productivity, meeting the consumption requirements of the households and making profit (Kahan, 2013). The appropriate farm management techniques are now more relevant in the face of the growing impact of the complex environment, changing technologies, and increasing globalization and competition on agriculture and rice production, in particular.

In this light, the success and survival of rice production in Nigeria will depend on the fact that farmers are equipped with all relevant characteristics that will enhance their skills to become better farm managers, achieve efficiency and higher productivity. Thus, in this section, the key characteristics of the sampled paddy rice farmers who were described as farm mangers or sole proprietors for this purpose are discussed. The description of the characteristics of the farmers was in respect of gender, age and marital status, level of education, off-rice farm income, the distance to the market, ownership of mills and means of transport (see Table 33).

Table 33

Level 1 Farmers' Characteristics in Sampled States in Nigeria

Items	Kaduna (*n*=100)	Nassarawa (*n*=100)	Niger (*n*=100)	Total (*N*=300)
Gender (%)				
Male rice farmers	98.0	95.0	97.0	94.3
Female rice farmers	2.0	5.0	3.0	5.7
Marital Status (%)				
Married	98.0	98.0	99.0	98.3
Unmarried	2.0	2.0	1.0	1.7
Off-rice cultivation Income (%)				
Yes	46.0	24.0	61.0	43.7
No	54.0	76.0	39.0	56.3
Ownership of means of transport (%)				
Bicycle	3.0	9.0	6.0	6.0
Motor-cycle	76.0	79.0	83.0	79.3
Car/Pick-up Vans	21.0	12.0	11.0	14.7
Others	0.0	0.0	0.0	0.0

Note. Compiled from field survey data.

The results confirmed that paddy rice cultivation business was largely dominated by male gender. The male gender accounted for 94.3% of the heads of paddy rice farm households, while the female counterpart only constituted 5.7%. The large gap is attributed to gender-based barriers, social norms and traditional practices as well as other religious barriers. Majority of the farmers were married accounting for 98.3% of total number of respondents.

The results further established that paddy rice cultivation was a major occupation as more than half of the respondents were not involved in any other agricultural cultivation, civil service and other employment. However, about 43.7% reported that they were engaged in cultivation of other agricultural crops, civil service and other industrial employment and as such earned off-rice income. At 79.3%, ownership of motor cycle was the dominant means of transport. However about 14.7% of the respondents were reported owing cars/pick-up vans and 6% owned only bicycle (see Table 33).

In efficiency studies, the level of education of farmers is used to gauge the available human capital in the farm. It is expected that the higher the level of education of a farmer, more robust is the ability of the farmer to adapt to changing farm technologies, develop better skills to manage the farms and increase the capacity to adopt changes in techniques and better farm inputs. Therefore, intermediate and higher education in agriculture continues to play a decisive role in rural development and sustainable agricultural production (Alam et al., 2009).

Table 34

Level 2 Farmers' Characteristics in Sampled States in Nigeria

Items	Kaduna (*n*=100)	Nassarawa (*n*=100)	Niger (*n*=100)	Total (*N*=300)
Level of Education (%)				
None	5.0	14.0	11.0	10.0
Koran	10.0	4.0	17.0	10.3
Adult literacy	2.0	1.0	1.0	1.3
Primary	23.0	25.0	30.0	26.0
Secondary	36.0	26.0	32.0	31.3
Tertiary	24.0	30.0	9.0	21.0
Ownership of Mills (%)				
Yes	0.0	0.0	0.0	0.0
No	100.0	100.0	100.0	100.0
Ownership of storage facility (%)				
Yes	73.0	61.0	54.0	62.7
No	27.0	39.0	46.0	37.3

Note. Compiled from field survey data.

A peek on the results showed that approximately 26.0% of the farmers finished primary school, 31.3% finished secondary school and 21.0% attended tertiary institutions. However, about 10.0%, 10.3% and 1.3% had no education, attended Koranic-based and adult literacy education, respectively. Evidences from the samples revealed that none of the farmers had paddy rice processing mill and have relied on contract mills for processing the paddy rice output. However, approximately 62.7% had storage facilities for both paddy rice and milled rice (see Table 34).

The average age of heads of the paddy rice farm households for all the samples was 47.5 years old. The average age of heads of the paddy rice farm households in Niger State was slightly higher at 49.1 years old, while in Kaduna and Nassarawa States the average age were slightly lower at 46.6 and 46.8 years old, respectively. However, the differences in average age were not statistically significant among the states as F (2,297) = 1.80; p = 0.167 (see Table 35).

The mean years of experience with paddy rice cultivation for all the samples was 9.2 years. Kaduna State recorded the least average years of experience with paddy rice cultivation at 8.9 years, while Niger State had the highest of 9.6 years. Notwithstanding the disparity, the differences in farming experiences among the states were not statistically significant as F (2,297) = 0.32; p = 0.730 (see Table 35).

Table 35

Level 3 Farmers' Characteristics in Sampled States in Nigeria

Items	Kaduna (*n*=100)	Nassarawa (*n*=100)	Niger (*n*=100)	Total (*N*=300)
Age				
Mean	46.6	46.8	49.1	47.5
F statistic		1.80^{NS}		
Standard deviation	10.5	11.2	9.2	10.4
Minimum	25.0	29.0	29.0	25.0
Maximum	70.0	75.0	70.0	75.0
Farming Experience				
Mean	8.9	9.1	9.6	9.2
F statistic		0.32^{ns}		
Standard deviation	6.0	6.8	7.0	6.6
Minimum	1.0	0.0	1.0	0.0
Maximum	30.0	30.0	31.0	31.0
Distance to Market (KM)				
Mean	5.6	3.6	2.3	3.8
F statistic		16.55*		
Standard deviation	5.2	4.6	1.7	4.3
Minimum	0.0	1.0	1.0	0.0
Maximum	20.0	17.0	10.0	20.0

Notes. Compiled from field survey data, and *ns* means not statistically significant and * is significance level at 1%.

The word "distance" refers to the amount of space between two geographical points (Kassali, Ayanwale & Williams, 2009). This definition includes concepts like time, place, transportation mode, quality of road, etc. all of which sum to the cost of mobility. For this study, the distance from the residence of the farmer to the local market, where he or she purchases farm inputs and sell the paddy and milled rice output represents the amount of space the farmer travels daily between two geographical points. Interest on this variable in the study is germane because costs involved in market transactions are particularly significant in rural economies where transportation facilities are poor and the local markets are segmented, while access to markets is difficult. These factors generally have specific impact on the productive and/or cost efficiencies of the entire agricultural sector, and paddy rice production in particular.

Table 35 further revealed that the average distance between homes of the farmers and the local market was moderate compared to the average distance between their homes and the farms. The average distance for all samples was 3.8 km, while the average distance to the farms was 6.24 km. Thus it is expected that the moderate distance will impact on productive efficiency by reducing cost of market transactions. Evidence from the field survey suggested further that average distance varied across the sampled states. While Niger State with an average distance of 2.3 km from homes to local markets was the lowest, Kaduna State had the highest average distance of 5.6 km. An investigation using the ANOVA test, showed that the differences in the mean distances from farm households' houses to the local market among the samples were statistically significant as $F\ (2,297) = 16.55; p < 0.001$.

Farm Resources and Output Management

This section analyzed the management practices of the sampled paddy rice farm households. The analysis was in respect of management of farm resources and output namely, land resources, labor resources, water, rice seed variety and seed, environmental, and output handling and marketing management.

Land resources management. The section dealt with the rice cropping patterns in sampled states and associated activities of rice cultivation. The respondents were also asked to indicate whether the farm plots are located in government provided irrigation facilities and how many times they harvested crops in the facilities per annum. Information was also obtained from the respondents on the use of green manure as a way of rejuvenating the soil.

Paddy rice production in the sampled states consisted of a sequence of activities that are timed. Erenstein et al. (2003) discussed the main activities in paddy rice production in Nigeria to include: land preparation, crop establishment through planting and transplanting, weed management; management of pests, fertilizer application, bird control and harvest and post-harvest management. However, the timing of these activities varies by production systems and states. Figure 12 identified the cropping patterns of the production systems and the farming activities by types of production systems in the sampled states.

Under the upland production system, land preparation starts early in January and lasts till May thus, taking advantage of the early rains for the timely establishment of rice crop. Contrastingly, in the lowland rice fields land preparation begins by April and ends June. In the irrigated system, land preparation activity begins in April and ends around August. The planting of the seeds or crop establishment by one of the following methods namely: direct seeding, broadcasting or transplanting of seedlings usually commences at different times in the various production systems. Whereas it takes place between March and May in the upland rice fields during the onset of the rains, the activity generally lasts from April to June in the lowland rice fields.

The weeding activity also takes place between May and July while the pest management commences in May and ends in June in the upland fields. On the contrary, in the lowland fields and the irrigated system the activity takes place in June and September and June to November.

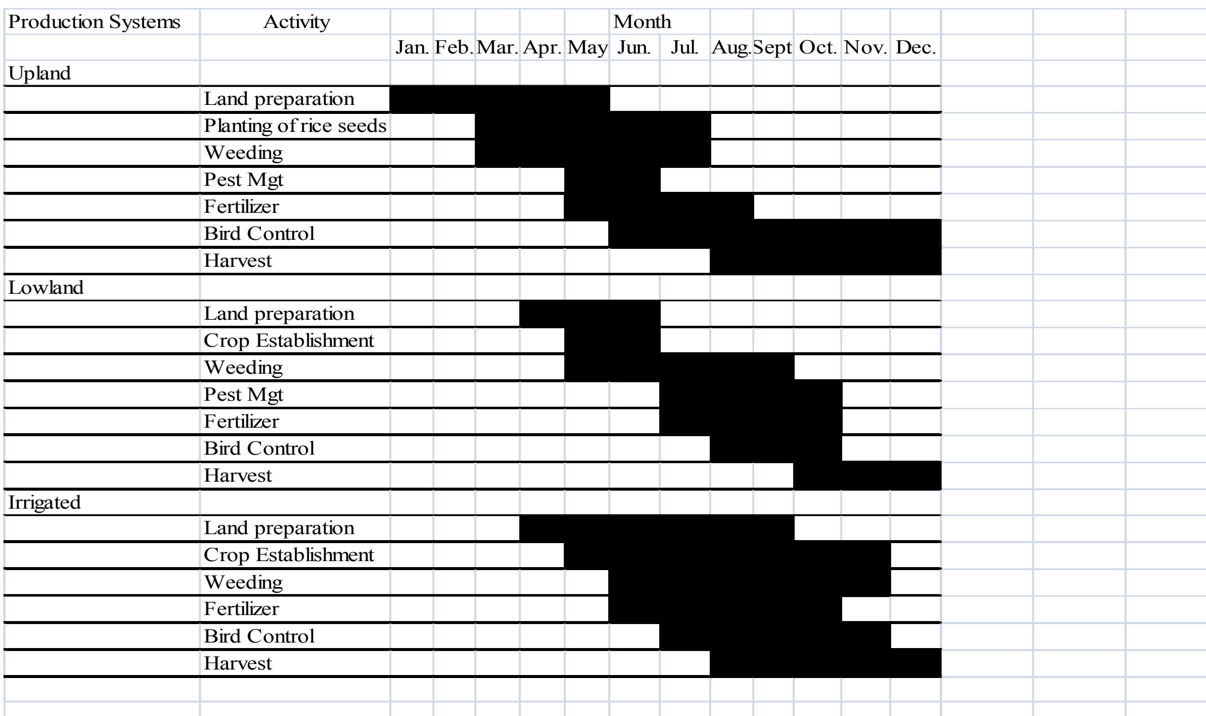

Figure 12. Cropping patterns for paddy rice cultivation in sampled states
Note. Compiled from the field data.

The rice harvest and post-harvest management in the upland rice fields starts in August and lasts till December but in the lowland fields it takes place between November and December. In the irrigated system it begins in August and ends in December.

The results of the fieldwork equally revealed that only 7.0% of the respondent paddy rice farm households cultivated under irrigation facilities. The proportion of paddy rice farmers that cultivated under irrigation was 16.0% in Kaduna State, while only 5% cultivated under irrigation production system in Niger State. However, irrigation production system was completely absent in Nassarawa State. Due to poor irrigation facility, the field work found that only 6.3% of the paddy rice farm households were able to harvest rice output two times in a year and none for three harvests but 93.7% harvested only once for all samples.

Table 36

Land Resources Management Practices

Items	Kaduna (*n*=100)	Nassarawa (*n*=100)	Niger (*n*=100)	Total (*N*=300)
Irrigation system rice cultivation (%)	16.0	0.0	5.0	7.0
No. of harvests per year (%)				
One harvest per year	85.0	100.0	96.0	93.7
Two harvests per year	15.0	0.0	4.0	6.3
Three harvests per year	0.0	0.0	0.0	0.0
Application of green manure (%)	34.0	5.0	13.0	17.3

Note. Compiled from field survey data.

In terms of the recovery of soil nutrients from the previous season cultivation, the result confirmed that only 17.3% of the paddy rice farm households applied the green manure as additional source of nitrogen to the rice fields. The proportion was higher in Kaduna State as about 34.0% of the farm households were able to use green manure for soil nutrients recovery but was lowest in Nassarawa State (see Table 36).

Labor resources management. The paddy rice farm households labor resources management practices was discussed using two dimensions, first human resources management practices and second, machinery management practices. The discussion is apt because the paddy rice cultivation business is labor intensive involving many activities such as preparation of land, crop establishment through planting and transplanting, weed and disease control, harvesting and post-harvesting activities.

Table 37

Hired Labor Use in Paddy Rice Farms in Sampled States in Nigeria

Items	Kaduna (*n*=100)	Nassarawa (*n*=100)	Niger (*n*=100)	Total (*N*=300)
Use of hired labor (%)				
Use of hired labor	100.0	100.0	100.0	100.0
Non-use of hired labor	0.0	0.0	0.0	0.0
Hired labor (No. Employed)				
Mean	10.7	10.0	9.3	10.0
F statistic		1.26^{ns}		
Standard deviation	7.0	6.2	5.3	6.2
Minimum	0.0	2.0	3.0	0.0
Maximum	40.0	40.0	35.0	40.0
Hired labor days				
Mean	110.4	108.8	67.8	95.7
F statistic		3.98**		
Standard deviation	149.7	129.9	68.4	122.3
Minimum	0.0	6.0	6.0	0.0
Maximum	840.0	750.0	420.0	840.0

Notes. Compiled from field survey data, and *ns* means not statistically significant and ** is significance level at 5%.

To achieve a cost minimization objective, the respondents were expected to adopt an effective use of family labor, labor exchange and hired labor as well as applying appropriate use of farm machineries. Thus, three important sources of labor input as explained earlier in Africa are family labor, labor exchange practices and hired labor. An earlier section has discussed the details of family labor thus this section discussed the details about hired labor and labor exchange and therefore, established the relationship between the three labor inputs in paddy rice cultivation.

Thus, the results of the field work revealed that all the respondents employed hired labor during the cropping season. Hired labor employed in the paddy rice farms was an average of 10.0 persons per farm during the cropping season. While there were notional differentials in the average number of employees across the samples, the test of equality of means discovered that the differences across the samples were not statistically significant as $F\ (2{,}297) = 1.26$; $p = 0.282$ (see Table 37).

Overall total number of employees in the rice farms was 3,006 persons for the season who worked for an average of 95.7 days. However, the average number of days worked by each employee differed across the three samples. While Kaduna State had the highest average number of days worked at 110.4 days per season, Niger State recorded 67.8 days and Nassarawa was 108.8 days. Further results showed that the differences in the mean number of days were statistically significant as $F\ (2{,}297) = 3.98$; $p < 0.05$.

Evidence from the field work also indicated that only 1.3% of the paddy rice farm households employed the services of labor exchange, mainly in Kaduna State. Labor exchange was a communal effort of labor engagement. In this circumstance, communities show a sense of togetherness and they work in each other individual farms in turns. There are no monetary attachments but only the farm household that uses the service of the community provided food and drinks for the community at the farms for that day. This form of labor input was found not relevant in rice production in the sampled states.

Table 38 showed that the mean daily wage for hired labor in all the samples was ₦856.2 ($4.3), amounting to an average total wage bill for a farm of ₦85, 256.8 or $432.8 in a cropping season. The average daily wage for an employee and total wage bill for a farm, however varied from one sample to another. For instance, Kaduna State recorded the highest daily average wage for an employee and total wage bill for a farm in a cropping season at ₦903.5 and ₦109, 570.5, respectively.

Table 38

Hired Labor Daily Wage and Total Wage Bill

Items	Kaduna (*n*=100)	Nassarawa (*n*=100)	Niger (*n*=100)	Total (*N*=300)
Hired labor wage (Naira/day)				
Mean	905.5	901.0	763.0	856.2
F statistic			11.28*	
Standard deviation	289.2	178.6	239.8	248.5
Minimum	0.0	400.0	200.0	0.0
Maximum	1500.0	1500.0	1000.0	1500.0
Total hired labor wage (Naira/farm)				
Mean	109570.5	94504.0	51696.0	85256.8
F statistic			6.47*	
Standard deviation	159732.8	114671.1	56178.5	120207.2
Minimum	0.0	6000.0	3000.0	0.0
Maximum	806400.0	750000.0	420000.0	806400.0

Notes. Compiled from field survey data, and * is significance level at 1%

Furthermore, Niger State had the lowest as the mean daily wage for an employee and total wage bills for a farm in a cropping season were ₦763.0 and ₦51, 696.0, respectively. In addition, the field data however, showed that the differences in the mean daily wage for a hired employee and total wage bill for a farm for the three samples were statistically significant as $F\ (2,297) = 11.28; p < 0.001$ and $F\ (2,297) = 6.47; p < 0.001$ (see Table 38).

Mechanization in the sample states is becoming very popular because of the realization by paddy rice farm households that the application of modern farm machineries implies human labor-cost saving. Farm machineries use in land preparation, planting and transplanting and harvesting activities could generate cost saving in terms of the massive use of both family and hired labor for these tedious activities.

Also, timeliness of farming operations can be achieved, the result being that yield is improved upon generally and thus increases the yield quality from farms leading to self-sufficiency in local rice production (Adamade & Jackson, 2014). An earlier result indicated that ownership of farm tractors was almost absence in all the samples however, the results from the field survey showed that the farmers hired tractor services available in their local markets and/or the ADPs.

A review of Table 39 confirmed that 56.7% of the paddy rice farm households in all the samples engaged the services of farm tractors either from the local market (40.2%) or government agent (59.8%). Specifically, Kaduna State was outstanding as 81.0% of the paddy rice farms engaged the services of farm tractors and the government tractor hiring service was the only source used. On the contrary, the local market tractor service accounted for 65.1% and 88.4%, while the government source only provided services to

34.9% and 11.6% of the paddy rice farm households in Nassarawa and Niger States, respectively.

The results indicated that the tractors worked for an average of 1.7 days during the cropping season at an average daily amount of ₦9, 315.7 and ₦39, 426.5 for the government and local market tractor services, respectively. Further investigation revealed that all the paddy rice farmers that owned farm machineries maintained the equipments using external workmen as such incurred maintenance cost.

Table 39

Use of Tractor Services by Paddy Rice Farm Households in Sampled States

Items	Kaduna (n=100)	Nassarawa (n=100)	Niger (n=100)	Total (n=300)
Machine hire (%)	81.0	46.0	43.0	56.7
Numbers of days worked (Average/farm)	2.3	1.4	1.4	1.7
Sources of Hire (%)	100.0	100.0	100.0	100.0
Government	100.0	34.9	11.6	59.8
Market	0.0	65.1	88.4	40.2
Average price of hiring (Naira/day)				
Government	8,582.7	15,937.5	0.0	9,315.7
Market	0.0	38,000.0	40,552.6	39,426.5

Note. Compiled from field survey data.

Water management in rice fields. The major source of water for the rice fields in the sampled states is rainfall. Nonetheless, in the irrigated areas, the irrigation projects provided water source for late planting season, thus allowing the respondents to harvest the paddy rice twice per annum. Since majority of the farmers depended on rainfall, the variation in weather conditions in the selected states had major impact on output performance by paddy rice farm households. Water management techniques used by paddy rice farm households are discussed below.

Evidence from Table 40 revealed that the paddy rice farmers checked water levels in the rice fields regularly, aimed at preventing flooding. Approximately, 66.3% of the farms admitted that they checked the water level in the rice fields based on their perception of the existing rainfall conditions. About 30.4% checked the water levels every week, while only 3% checked the water level every two weeks. Before harvesting paddy rice, farmers are expected to drain the water level in the rice fields. The result from the field work revealed that only 9.3% of the paddy rice farm households drain the water level before harvesting.

Table 40

Water Level Management Techniques by Paddy Rice Farmers

Items	Kaduna (*n*=100)	Nassarawa (*n*=100)	Niger (*n*=100)	Total (*N*=300)
Water level and control during production (%)				
Checking every week	26.0	29.0	37.0	30.7
Checking every two weeks	4.0	4.0	1.0	3.0
Checking depending on situations	70.0	67.0	62.0	66.3
Water drainage before harvesting (%)				
Drainage	14.0	4.0	10.0	9.3
No drainage	86.0	96.0	90.0	90.7

Note. Compiled from returns from field survey data.

Rice seed varieties and seed management. The paddy rice seed being the fundamental input in rice crop production, its high quality forms the basis of high farm efficiency and productivity. Although, the cost of seed is found to be a very small component of the total cost of paddy rice production, the use of high yield and certified rice seed varieties are necessary conditions that could impact on the technical, allocative and economic efficiencies of the paddy rice farm households. Therefore, in this study the rice seed variety was categorized into two groups namely improved and traditional varieties. Fourteen major rice seed varieties planted by our paddy rice farm households were identified during the field work. The rice seed varieties planted comprised 6 improved varieties and 8 traditional varieties (see Table 41).

Table 41

Rice Seed Varieties used by Paddy Rice Farm Households in Sampled States

Varieties	*Type*	*Average year of use*	*Growing period in months*	*Production System*	*Grain type*	*% of Farms Used Seed Variety*
FARO varieties	Improved	4.7	3.0	Lowland	Long	85.0
NERICA varieties	,,	2.8	3.0	Lowland	Long	17.0
BW	,,	2.0	4.0	Lowland	Long	0.7
Jollof Rice	,,	1.0	4.0	Lowland	Long	0.3
A.I.C.	,,	3.0	3.0	Upland	Long	1.3
Oga	,,	1.0	4.0	Lowland	Long	0.3
Alura	Traditional	7.4	4.0	Lowland	Small	7.7
Achiko	,,	6.0	4.0	Lowland	Small	0.7
Paper	,,	2.0	4.0	Lowland	Long	0.7
Jemila	,,	4.5	4.0	Upland	Long	7.0
Yan Kura	,,	6.7	4.0	Lowland	Long	3.0
Yan Hassan	,,	5.4	4.0	Lowland	Small	1.7
Badegi	,,	5.5	4.0	Lowland	Medium	0.7
Yan Daganame	,,	3.3	4.0	Lowland	Medium	0.3

Note. Compiled from field survey data.

Some of the improved seed varieties were also found to have different categories. For example, FARRO and NERICA varieties were the improved varieties that have subcategories. All of the seed varieties have growing periods of between 3 to 4 months and the average year of cultivation ranged from 1 to 7.4 years. Most of the seed varieties were for lowland production and many were of the long grain type. In addition, the field survey revealed that about 26.7% of the paddy rice farm households cultivated a mixture of two to four varieties of paddy rice seeds. In some cases, the paddy rice farm households combined during planting both the improved and traditional varieties in their farms.

Thus, about 85.0% of the 300 rice farm households interviewed planted the widely accepted improved rice FARO seed varieties (mainly FARO 15, 44, 47,55, 57, dan China, 2PC and Willey) alone or together with other improved and traditional varieties, while only 17.0% used the NERICA varieties or combined with other improved and traditional varieties. The common traditional variety used by the paddy rice farm households was the Alura rice seed as approximately 7.7% of the farms used it during the season (see Table 41).

The paddy rice farm households were asked to identify the sources of the rice seeds they cultivated. The two sources identified were states' ADPs, while the second source was the local market. Purchase from the government agency was subsidized but paddy rice seeds purchased from the local market were largely the traditional varieties, which were procured at the market rate. The results of the survey confirmed that about

65.7% of the paddy rice farm households in all the samples procured the rice seeds planted from government source, while only 34.3% obtained the seeds from the markets.

The result further revealed that about 93.0% of the paddy rice farm households in Niger sourced the rice seeds planted from government agency, while in Kaduna and Nassarawa States only 74.0% and 30.0% obtained the seeds from the agency of government, respectively. Generally, farmers in Nassarawa State depended mainly on the local market for seeds as 70.0% of the farm households purchased rice seeds from the open local markets (see Table 42).

Table 42

Sources of Seed Procurement and Seed Management

Items	Kaduna (*n*=100)	Nassarawa (*n*=100)	Niger (*n*=100)	Total (*N*=300)
Sources of Seed Procurement (%)				
Government	74.0	30.0	93.0	65.7
Market	26.0	70.0	7.0	34.3
New Seed replacement (%)				
Replace every crop planted	65.0	49.0	10.0	41.3
Replace every two crop planted	24.0	47.0	80.0	50.3
Replace every three crop planted	11.0	4.0	10.0	8.3
Seed planting methods (%)				
Direct Seeding	97.0	17.0	93.0	69.0
Transplanting from Nursery	2.0	0.0	3.0	1.7
Broadcasting	1.0	83.0	4.0	29.3

Note: Compiled from the field survey.

Seed replacement means that the farmer replaces the old variety planted with a new seed either of the same improved variety or a different variety. Thus, seed replacement rate (SRR) is referred to as the number of times a seed lot was used from the previous cropping season. For example, in many regions, rice farmers' plant seeds in the current season and after harvesting they preserve some seeds from the previous season output, which are used for planting in the new season (Kakoty & Barman, 2015).

The results of the field survey showed that only 41.3% of the paddy rice farm households replaced new seed every cropping season, therefore do not accumulate seeds from the current harvest for planting in the next season. On the contrary, 50.0% of the farmers replaced crop seeds after using the collections from previous two seasons and only 8.3% replaced rice seeds with the new seed variety after every three crops. This means that these farmers bought seed once and used it for about three cropping seasons by collecting seeds from the previous paddy rice output and keeping it for the next cropping season. The implication from this revelation is the possible negative effect on productive efficiency of our paddy rice farm households. This is true because the use of quality and fresh new seed can increase productivity and enhance productive efficiency. Thus, lack of quality seed and a high replacement rate are main challenges of bridging the vast yield gap.

A further examination of the results showed that about 65.0% of the rice farm households in Kaduna replaced new seeds after every cropping season. Contrastingly, only 49.0% and 10.0% of the farm households in Nassarawa and Niger States respectively, replaced new rice seeds after every cropping season. The results exposed further that about 80.0% of the farmers in Niger State replaced new seeds after every two crops, while

49.0% and 24.0% of the farmers in Kaduna and Nassarawa States replaced seeds with new seeds after every two cropping season, respectively.

Direct seeding was the most popular method of planting paddy rice seeds in all samples as 69.0% of the farm households used the method to establish the rice crop during the season. Specifically, the method was widespread because of the availability of cheap family labor. Overall, the use of the two other methods namely the transplanting from nursery and broadcasting were found less popular. The results showed that only 1.7% and 29.3% of the paddy rice farm households used these methods of rice crop establishment, respectively. However, the results exposed that the broadcasting method was prevalent in Nassarawa State as approximately 83.0% of the farmers used the method (see Table 42).

Environmental detrimental inputs management. Tillman et al. (2002) poised that supply of agricultural products and ecosystem services are essential to human existence and quality of life. Nevertheless, recent agricultural practices have had inadvertently, detrimental impact on the environment and on the ecosystem services. This highlights the need for more sustainable agricultural methods. The following section discussed the rice farm household's ability to manage the environmental detrimental inputs in paddy rice production. Thus, the discussion focused mainly on the use of fertilizer, herbicide and insecticide/fungicide by rice farmers to boost yield and productivity that will impact on production efficiency.

All farmers in the three samples applied chemical fertilizer for rice production. Two common fertilizer used were the NPK and the Urea. In addition, approximately

90.0% of the farmers in all the samples applied chemical fertilizer two times during the cropping season, while only 10.0% applied it once. The major source of chemical fertilizer procurement was through government ADPs in the respective states. Precisely, 83.7% of the farmers procured chemical fertilizer from the government agency at subsidized price, while 17.3% of the paddy rice farm households purchased from the market (see Table 43).

Table 43

Fertilizer Input Management and Sources of Procurement

Items	Kaduna (*n*=100)	Nassarawa (*n*=100)	Niger (*n*=100)	Total (*N*=300)
Use of fertilizer (%)				
Yes	100.0	100.0	100.0	100.0
No	0.0	0.0	0.0	0.0
Number of Application of fertilizer (%)				
Once	4.0	22.0	4.0	10.0
Twice	96.0	78.0	96.0	90.0
Sources of fertilizer procurement (%)				
Government	96.0	53.0	99.0	82.7
Market	4.0	47.0	1.0	17.3

Note. Compiled from field survey data.

Herbicide is also a major chemical input in paddy rice production, which is used for weed control by rice farm households. The results from the survey returns showed that approximately 99.0% of the rice farm households made use of herbicides to control weed in the rice fields. Contrary to the application of chemical fertilizer, about 69.0% of the rice farm households applied herbicide once during the cropping season, while 30.0% applied twice.

Table 44

Herbicide Input Management and Sources of Procurement

Items	Kaduna (n=100)	Nassarawa (n=100)	Niger (n=100)	Total (N=300)
Use of herbicides (%)				
Yes	99.0	100.0	98.0	99.0
No	1.0	0.0	2.0	1.0
Number of applications of herbicides (%)				
None	1.0	0.0	2.0	1.0
Once	56.0	82.0	69.0	69.0
Twice	43.0	18.0	29.0	30.0
Sources of herbicides procurement (%)				
Government	14.0	27.0	1.0	14.0
Market	86.0	73.0	99.0	86.0

Note. Compiled from field survey data.

The findings also showed that the rice farm households in Nassarawa State were more cautious in the use of chemical herbicides as approximately 82.0% of the rice farmers applied herbicides once, compared to 69.0% and 56.0% in Niger and Kaduna States, respectively. Further examination of survey returns revealed that about 86.0% of the rice farmers in all the samples purchased chemical herbicide from the market, while 14.0% obtained the input from the government source. However, about 27.0% of the farmers in Nassarawa State obtained chemical herbicide from the government agency (see Table 44).

Table 45

Insecticide and Fungicide Input Management and Sources of Procurement

Items	Kaduna (*n*=100)	Nassarawa (*n*=100)	Niger (*n*=100)	Total (*N*=300)
Use of insecticide/fungicide (%)				
Yes	90.0	32.0	10.0	44.0
No	10.0	68.0	90.0	56.0
Number of Applications of insecticide/fungicides (%)				
None	10.0	65.0	90.0	55.0
Once	45.0	26.0	4.0	25.0
Twice	45.0	9.0	6.0	19.3
Sources of insecticide/fungicide procurement (%)				
Government	14.0	18.0	6.0	12.7
Market	86.0	82.0	94.0	87.3

Note. Compiled from field survey data.

Chemical insecticide and fungicide are other chemical inputs used by rice farm households to control rice diseases, insects and pests. From the field work results and in all farms, 44.0% of the paddy rice farm households applied insecticide and fungicide of various types in the rice fields. Approximately 90.0% of the rice farm households in Kaduna State applied insecticide and fungicide in their farms, while only 10.0% of the farmers applied the chemicals in Niger State. The result further showed that only 25.0% of the farmers applied it once and 19.3% applied the chemicals twice during the cropping season. Approximately 87.0% of the farmers that used the chemical procured it from the local markets but 12.7% of them purchased from government agency (see Table 45).

Rice Farming Information Management

Information on rice production has received relevant attention in the literature. Bachhav (2012) opined that information is an integral part of agriculture sector as it helps to enhance farm productivity and efficiency of farm households. Providing information on weather trends, best practices in farming, access to market information on a timely basis will enhance the decisions of farm managers on what crops to plant, technology to use and where to buy the inputs and sell the output. Thus, the information needs of farmers change from time to time as a result of changes in technologies, environment, agricultural policies and emergence of agricultural innovations (Benard, Dulle & Ngalapa, 2014).

Table 46

Sources of Rice Farming Information of the Farmers in Sampled States

Items	Kaduna (*n*=100)	Nassarawa (*n*=100)	Niger (*n*=100)	Total (*N*=300)
Sources of agricultural information (%)				
Radio	11.0	2.0	0.0	4.3
Television	1.0	0.0	0.0	0.3
Agricultural bulletin	0.0	0.0	0.0	0.0
Agricultural extension officers	88.0	98.0	71.0	85.7
Farmers cooperative society	0.0	0.0	18.0	6.0
Others	0.0	0.0	11.0	3.7
Access to extension officers (%)				
Yes	92.0	100.0	95.0	95.7
No	8.0	0.0	5.0	4.3
Average number of times of access in a month	2.6	2.1	2.1	2.3

Note: Compiled from field work returns.

Therefore, this section discussed available rice technology and market information as paddy rice farm households were asked to identify the major sources of information and their accessibility to government appointed agricultural extension agents and services. The results of the survey indicated that the major source of rice farming information for the farmers in all the samples was the agriculture extension officers. Approximately 85.7% of the farmers reported that the agriculture extension officers were the major sources of rice farming information. The other supporting sources of information to the rice farm households were farmers' cooperative societies (6.0%), radio (4.3%), and others (3.7%) mainly fellow rice farmers. Thus, the result further revealed that 95.7% of the rice farm households in all the samples had access to the government appointed agriculture extension officers in an average of more than two times a month (see Table 46).

Production Activities: Input and Output Management

This section discussed the production activities of the paddy rice farm households focusing on inputs used and the paddy rice output produced and its management and marketing. Thus, the average inputs and outputs were discussed and the findings were later used to evaluate the profitability of rice production in our sampled states. Furthermore, the findings were also employed to estimate the technical, allocative and economic efficiency scores of the rice farm households also in a later section.

Input use in paddy rice production. Inputs in paddy rice production by sampled farm households were divided into two categories namely fixed and variable inputs (Mailena et al., 2013). Fixed input was defined as an item required for the production of the paddy rice output, which could not vary in the short-run or vary as paddy rice output changes. Conversely, a variable input is a production item used however, varied in the short-run depending on the output produced. Thus, fixed input was categorized as an item that was constant during the production season but could vary in the long-run.

In rice production in the sampled states, the main fixed input is area of land cultivated in hectares. Thus, in the short-run, land was the constant input in all the samples. As indicated earlier, the paddy rice farm households in all the samples were described as fragmented landholders. Thus, the mean farm size was 2.3 hectares but was highest in Kaduna State (2.6 ha) and lowest in Niger State (2.0 ha).

Table 47

Summary Statistics of Inputs Used and Paddy Rice Output

Inputs	Measure	Kaduna (*n*=100)		Nassarawa (*n*=100)		Niger (*n*=100)		Total (*N*=300)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Area	Ha	2.6	2.1	2.2	1.4	2.0	1.4	2.3	1.8
Fertilizer	KG/ha	288.7	163.2	312.4	174.8	304.3	139.8	281.1	159.7
NPK type	KG/ha	227.4	165.2	223.5	193.0	266.4	150.8	220.2	171.1
Urea type	KG/ha	50.5	101.2	88.8	138.0	36.9	114.6	55.5	120.6
Rice seeds	KG/ha	113.7	93.9	93.0	28.2	95.8	20.4	100.9	58.3
Herbicides	liters/ha	5.7	4.0	6.3	2.6	8.2	4.0	6.7	3.4
Insecticides and fungicides	liters/ha	7.0	7.1	1.3	2.2	0.6	1.8	3.0	5.3
Labor	man-hr/ha	418.4	277.0	543.2	307.4	401.9	277.0	454.5	282.8
Family labor	man-hr/ha	96.8	152.9	135.2	180.8	95.4	146.3	109.2	161.2
Hired labor	man-hr/ha	318.1	266.3	407.4	287.9	306.4	235.3	344.0	267.0
Machine labor	man-hr/ha	5.8	3.2	3.0	3.2	2.1	2.6	3.6	3.4
Green manure	KG/ha	296.1	534.5	86.0	341.1	85.0	240.6	155.7	402.7
Paddy rice output	KG/ha	3737.3	2099.5	1747.7	867.5	2190.3	867.5	2558.4	1591.7
F statistic				60.01*					

Notes. Compiled from field survey data, and * is significance level at 1%.

The major variable inputs used by rice farm households to produce paddy rice output in all the samples were: chemical fertilizer, rice seeds, herbicides, insecticides and fungicides, human labor, machine labor and green manure. The results showed that in all the farms the average use of chemical fertilizer was 281.1 kg per hectare. The farmers used more of NPK fertilizer type at an average of 220.2 kg per hectare, while the average input use of Urea fertilizer type was 55.5 kg per hectare. In addition, average chemical fertilizer used for a hectare cultivated by rice farm households in Nassarawa State was more at 312.4 kg but was lower in Kaduna State at an average of 288.8 kg per hectare.

The average seed rate was 100.9 kg for a hectare of rice field that was cultivated but varied across the states. Accordingly, the average seed rate was marginally lower than the recommended seed rate of 107 kg per hectare (Nwilene et al, 2008). However, the average seed rate used by rice farm households in Kaduna at 113.7 kg per hectare was higher, compared to the recommended seed rate. Similarly, the average amount of herbicides used by farm households in all the samples was 6.7 liters for a hectare of rice field cultivated.

The result in Table 47 revealed that rice farm households in Niger State used an average of 8.2 liters/ha, which was more than the average of all farms, while rice farm households in Kaduna used the least of 5.7 liters/ha. On an average basis, the rice farms for all samples used an average of 3 liters/ha of insecticides and fungicides. However, the farmers in Kaduna State were reported using more of the chemicals at an average of 7.0 liters per hectare of farm land.

Evidence from the field work also showed that the average man-hour worked for each hectare of rice farm land was 454.5 hours per hectare. A further breakdown indicated that family members were engaged in the rice fields for an average period of 109.2 hours. On the contrary, hired labor was engaged for an average time of 344.0 hours. At 543.2

hours per hectare labor input was generally higher in Nassarawa State than any other state. A breakdown of labor in the state revealed that family labor worked in the rice fields for an average period of 135.2 hours per hectare during the cropping season, while hired labor worked for an average of 407.4 hours in the same season (see Table 47).

Machine labor employed in the rice fields mainly for land preparation also worked for an average of 3.4 hours for a hectare of farm land during the cropping season. The returns further revealed that rice farm households in Kaduna State used the services of tractors more as the average man-hour worked by owned and hired machine was 5.8 hours in the cropping season.

Furthermore, the average amount of green manure as an organic fertilizer used to increase nitrogen in the soil was 155.7 kg for a hectare of rice farm. Further evidence explained that paddy rice farms in Kaduna State used more of green manure than farmers in other states as the farmers applied more of organic fertilizer than chemical fertilizer, which was 296.1 kg for a hectare of rice field. However, farm households in Niger State at 85.0 kg for a hectare recorded the least application of green manure below all samples average application.

Paddy rice output and management. Paddy rice output for a hectare of farmland for all the samples ranged between 1000 kg and 14000 kg. The average output of the whole farms was 2,558.7 kg for a hectare during the cropping season. However, the average paddy rice output harvested during the period varied across the three group samples. For instance, average output in Kaduna State was highest, as the state sample recorded an average paddy rice output for a hectare of rice field of 3,737.3 kg. On the contrary, the average paddy rice output per hectare of rice field for Nassarawa State sample was the least at 1,747.7 kg. Thus, a further analysis indicated that the differences in the mean paddy rice output for a hectare of rice field across the three samples were statistically significant as F (2,297) = 60.01; $p < 0.001$ (see Table 48).

Paddy rice output management was the cornerstone of the objective of cultivating paddy rice by farm households during the cropping season. As shown earlier, the three objectives of rice farm households varied. First, some farm households' objective was subsistence rice farming as such the rice farm households produced exclusively for consumption by members of the family. The second category of rice farming objective was semi commercial that is they produced for household consumption and sold the surplus in the local market. Finally, the last category objective was purely commercial in which case, the farm households produce solely for disposal at the paddy rice local market. Earlier results showed that our sampled rice farmers were largely cultivating the paddy rice based on an objective of semi commercial, while a few cultivated with a sole commercial objective. Thus, the farmers were asked to indicate the capacity and type of storage facilities they have as well as the channels of marketing the paddy and the milled rice output.

Table 48

Storage Capacity and Type, and Sources of Marketing Paddy and Milled Rice

Items	Kaduna (n=100)	Nassarawa (n=100)	Niger (n=100)	Total (n=300)
Capacity of Storage Facility (KG)				
Mean	10,360.0	1,438.5	3,665.0	5,154.5
F-statistic		33.62*		
Standard Deviation	12,030.6	2,435.0	6,459.3	8,838.7
Type of storage facilities (%)				
Local silos	58.3	57.4	40.4	53.0
Modern silos	13.9	4.9	5.8	8.6
Rooms	27.8	37.7	53.8	38.4
Channels of marketing Paddy rice (%)				
In the farm	4.0	4.0	1.0	3.0
Trough the paddy local market	95.0	86.0	93.0	91.3
Direct sale to millers	1.0	10.0	6.0	5.7
Direct sale to government buying agent	0.0	0.0	0.0	0.0
Channels of marketing milled rice (%)				
Self marketing	50.8	68.1	25.0	48.7
Through middlemen	49.2	31.9	75.0	51.3
Others	0.0	0.0	0.0	0.0

Notes. Compiled from field survey data, and * is significance level at 1%.

From survey returns, it was identified that the average storage capacity of various types in all the samples was 5,154.5 kg and this consisted mainly of local silos (53%) and rooms (38.4%). The ownership of modern silos was insignificant as it accounted for only 8.6% of the total storage capacity. This has implication on the cost efficiency and profitability of the paddy rice farm households businesses as they recorded huge post-harvest losses in paddy output due to insect attacks. However, a further evaluation of the mean of rice storage capacities across the three groups showed that there were statistical significant differences as F (2,297) = 33.63; $p < 0.001$.

For instance, the average paddy output storage facility owned by rice farm households in Kaduna State was 10,360.0 kg, which was two times the size of the average size of all the samples. The average sizes at 1, 438.5 kg and 3, 665.0 kg for Nassarawa and Niger States, respectively were far below all samples average. Approximately, 91.3% of the rice farm households who disposed the paddy rice output used the channel of the local paddy rice local market. An important feature of paddy rice marketing practices by the farm households was the absence of the channel of government policy on bulk purchase facility. Perhaps, this may be attributed to lack of trust on the government last resort purchase policy. Similarly, the channel for the marketing of the local milled rice was through middlemen, accounting for 51.3% of the total milled rice sold. In realization of the impact of the middlemen on rice income, about 48.7% of them marketed the milled rice by themselves (see Table 48).

Problems of paddy rice milling and marketing. The farmers were asked their opinions on the problems associated with milling and marketing of milled rice. These reactions are summarized in Table 49. The results revealed that 25.4% of the farm households that milled paddy rice output identified the most severe problem during milling as breakage of rice seeds.

In addition 22.2% of the farm households identified constant breakdown of milling plants that belonged to the local small commercial millers. The other problems of paddy rice milling that were identified by the rice milling farm households in the whole sample were: high cost of milling (21.1%); inadequate number of milling plants (20.5%) and others (10.8%). One major problem under others was the inability of the milling machines to clean up the rice properly and free the milled output of stones.

Table 49

Farm Households' Perceptions on Problems of Milling and Marketing of Milled Rice

Items	Kaduna (*n*=100)	Nassarawa (*n*=100)	Niger (*n*=100)	Total (*N*=300)
Problems of paddy output milling (%)				
Constant breakdown of plant	21.0	18.6	28.3	22.2
High cost of milling	16.1	27.1	18.9	21.1
Breakage of rice seeds during processing	43.5	15.7	17.0	25.4
Inadequate number of milling plants	9.7	20.0	34.0	20.5
Others	9.7	18.6	1.9	10.8
Problems of milled rice marketing (%)				
Poor grading and quality control for local rice	11.1	0.0	5.1	5.2
High incidence of broken grains	20.6	26.4	30.8	25.3
High cost of production	6.3	27.8	15.4	17.2
Low patronage of local rice	55.6	34.7	43.6	44.3
Lack of Government adequate support	1.6	2.8	0.0	1.7
Others	4.8	8.3	5.1	6.3

Note. Compiled from survey data.

They also identified the major problems hindering marketing of locally milled rice. Among the problems, about 44.3% of the paddy rice milling farm households complained that the low patronage of locally milled rice was a major hindrance to efficiency. Other problems identified during the field work were: high incidence of broken grains (25.3%); high cost of production (17.2%) and poor grading and quality control in local paddy rice milling (5.7%). However, only 1.7% complained of lack of government support to local rice production, while 6.3% complained of other related problems such as poor pricing of locally produced milled rice in Nigeria.

Input and Output Prices

Apart from the collection of the quantities of output in kilograms per hectare and the inputs per unit of measures, prices of output in kg and inputs in different units of measure were also obtained. The price at which the rice farm households sold their output ranged from ₦40 to ₦150 for a kg. The average price at which all the samples sold the output was ₦75.2 for a kg during the cropping season. However, the average price for output in kilograms during the period varied across the three groups. For instance, average price for a kg of output in Kaduna State was lowest at ₦59.6. On the contrary, the average price for a kg of output was highest at ₦92.9 in Nassarawa State. Thus, a further analysis indicated that the differences in the mean price of kilogram of output across the three samples was statistically significant as F (2,297) = 138.60; $p < 0.001$ (see Table 50).

Similarly the average price of inputs varied depending on the type of input. For example the average price of fixed input (land) was ₦1, 965.3 for all the samples. The average prices for a kg of the variable inputs in all the samples were NPK fertilizer (₦50.3); Urea fertilizer (₦ 16.4) and rice seeds (₦ 65.7). The average prices of herbicide, and insecticide/fungicide were ₦ 1, 124.1 and ₦457.3 for a liter, respectively. In the case of human labor, the average price for family labor was ₦250.0 and that for hired labor was ₦856.2. The average cost of machine hire for a day was ₦13, 059.0, while the average price for a kg of green manure was ₦15.0 (see Table 50).

Table 50

Summary of Prices of Rice Farm Inputs and Output

Prices	Measure	Kaduna (*n*=100)		Nassarawa (*n*=100)		Niger (*n*=100)		Total (*N*=300)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Area of land cultivated	Naira/ha	3,149.3	3,332.5	996.7	2,729.3	1,750.0	3,711.6	1,965.3	3,391.6
Fertilizer									
NPK type	Naira/kg	53.8	15.3	43.2	15.3	53.7	17.3	50.3	20.0
Urea type	Naira/kg	18.6	26.7	23.3	27.4	7.3	18.9	16.4	25.5
Rice seeds	Naira/kg	59.6	11.2	88.1	23.7	49.4	6.5	65.7	22.6
Herbicides	Naira/liter	1,018.0	158.5	1,010.8	158.5	1,343.5	249.2	1,124.1	244.3
Insecticide and fungicide	Naira/liter	913.3	327.8	370.0	574.1	88.5	267.7	457.3	534.8
Labor									
Family labor	Naira/day	321.0	289.0	271.0	212.6	158.0	149.9	250.0	233.9
Hired labor	Naira/day	905.5	289.2	900.0	179.2	763.0	239.8	856.2	248.5
Machine labor	Naira/day	6,967.0	4,832.5	16,800.0	18,674.8	15,410.0	18,140.4	13,059.0	15,846.2
Green manure	Naira/kg	15.0	0.0	15.0	0.0	15.0	0.0	15.0	0.0
Paddy rice output	Naira/kg	59.6	8.5	92.9	19.2	73.1	13.0	75.2	19.8
F-statistic					138.60*				

Notes. Compiled from field survey data, and * is significance level at 1%.

Profitability Analysis of Paddy Rice Cultivation Business in Nigeria

In this section, an ex-post appraisal of the performances of the rice farm households in our samples was conducted. Accordingly, average profit for each of the rice farm was defined as average income receipts less average total cost of production for each farm including the average milling cost by rice farm households. Average farm income of the farm households was obtained by multiplying the price of output per kg with the total output sold. Similarly, the cost for each input was calculated by multiplying the price of the input per unit of measure with the quantity used. Total cost therefore was the summation of individual input costs including the fixed, variable, and processing costs.

Profitability of rice production in whole sample. The average total cost of inputs was categorized into fixed and variable costs. The total cost of paddy rice production in a cropping season ranged between ₦31, 635.0 and ₦1, 578,305.0 in all the samples. Thus, the average total cost for a rice farm in all the samples was ₦234, 769.0 for the 2014/2015 cropping season. The average total cost of production means that the cost of production of a kg of rice output was ₦91.8. The results revealed that the differences in average total cost across the state samples was statistically significant as F (2,297) = 5.77 for $p < 0.001$. Thus, the average fixed cost mainly the land rental fee from individuals/ communities or state governments amounted to ₦3, 227.3 and constituted only 1.4% of the average total cost of production during the cropping season (see Table 51).

Similarly, average cost of fertilizer input was ₦36, 975.0 for each rice farm, which was 15.7% of the average total cost. The cost of fertilizer input in each farm for the season comprised cost of NPK fertilizer (₦28, 918.8) and Urea type (₦7, 150.1). The average cost of purchase of rice seed was only 6.5% of the total cost, thus indicating that each farm spent during the cropping season an average amount of ₦15, 192.9 on purchase of rice seeds for planting. Hence, the survey results strongly confirmed the assertion that the cost for use of planting seed in paddy rice production was small compared to the cost of fertilizer and labor due to low SRR as explained previously.

Table 51

Cost Components for Rice Production

Items	Kaduna (n=100)		Nassarawa (n=100)		Niger (n=100)		Total (n=300)	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
Components (Naira)								
Area of land cultivated	6,547.0	9,330.1	1,150.0	3,307.1	1,985.0	4,551.9	3,227.3	6,704.4
Total fertilizer	39,673.4	39,493.1	35,318.5	32,344.4	35,933.0	39,273.2	36,975.0	37,094.7
NPK type	30,107.5	33,446.3	25,734.0	28,420.0	30,915.0	32,206.8	28,918.8	31,072.0
Urea type	6,900.9	16,147.3	9,584.5	15,416.0	4,965.0	23,460.6	7,150.1	18,731.2
Olam special fertilizer	2,500.0	17,943.5	0.0	0.0	0.0	0.0	833.3	10392.2
Kapal super fertilizer	165.0	961.5	0.0	0.0	53.0	530.0	72.7	635.5
Rice seeds	17,305.5	16,490.6	18,904.6	20,041.9	9,368.5	6,957.5	15,192.9	16,016.0
Herbicides	14,627.5	19,521.7	11,652.5	7,642.0	21,846.0	19,255.6	16,042.0	16,931.2
Insecticide / fungicide	18,222.5	32,578.6	3,199.5	6,217.8	1,044.0	3,101.6	7,488.7	20,639.4
Total labor	115,150.5	158,149.8	100,766.0	111,662.5	57,763.0	55575.7	91,226.5	118,443.1
Machine labor	14,546.0	13,043.2	28,600.0	43,595.2	21,200.0	30,220.4	21,448.7	31,954.0
Debt service payments	8,080.0	36,196.3	0.0	0.0	4,200.0	28,183.4	4,093.3	26,603.1
Other production costs	23,800.8	54,799.3	10,621.5	5,385.1	12,661.8	19,041.9	15,694.7	34,023.7
Milling cost	45,475.0	68,286.3	10,924.0	12,661.5	23,634.0	33,805.3	26,677.7	46,687.0
Total cost	293,081.7	279,774.3	221,466.6	196,476.8	189,758.8	169,643.2	234,769.0	223,832.7
F statistic			5.77*					

Notes. Compiled from field survey data, and * is significance level at 1%.

In addition, the evaluation of performances of the rice farm households' operations during the 2014/2015 cropping season revealed that the key component of average total cost for paddy rice production by the rice farm households was the average labor cost, constituting an estimated share of 38.9%, indicating an average cost of ₦91,226. 5. In the same vein, the average cost of machine labor in each rice farm constituted an estimated share of 9.1% of the average total cost. This implied that each rice farm spent an average of ₦21, 448.7 for hiring farm tractors for land preparations during the cropping season.

Furthermore, the results of the field survey revealed that each of the rice farms spent an average of ₦16, 042.0 to purchase herbicides for weed control. Thus, the share of average cost of herbicides in average total cost was 6.8%. However, the cost for the use of insecticide and fungicide, and the use of available credit facilities in the rice fields were highly insignificant as they constituted only 3.2% and 1.7%, respectively of average total cost of production. Additionally, the rice farm households incurred specific costs, which were grouped as "other cost". This constituted an estimated amount of ₦15, 694.7 or 5.3% of the average total cost of production.

Table 52

Components of ''Other Costs'' of Paddy Rice Production

Items	Kaduna (*n*=100)		Nassarawa (*n*=100)		Niger (*n*=100)		Total (*N*=300)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Transportation	8,952.0	1,240.8	8,626.0	881.0	8,700.0	0.0	8,759.3	886.7
Depreciation	5,123.5	50,101.6	0.0	0.0	1,990.0	17,639.8	2,371.2	30,636.8
Maintenance	259.0	2,208.1	0.0	0.0	105.0	1,000.7	121.3	1,399.0
Green manure	8,797.5	14,253.7	1,425.0	5,297.4	1,350.0	4,240.0	3,857.5	9,734.3
Others	30.0	300.0	0.0	0.0	0.0	0.0	10.0	173.2
Miscellaneous	638.8	302.4	570.5	228.5	516.8	198.9	575.4	251.3

Notes. Compiled from field survey data.

Equally, the rice farm households that milled harvested paddy rice output incurred cost that was categorized as milling cost. The data were obtained from the milling farm households who were asked to indicate the price paid to local millers in their environment for every 100 kg bag milled. The prices indicated for milling 100 kg bag ranged between ₦400.0 and ₦600.0. By implication the price paid for a kg of paddy rice milled ranged between ₦40 and ₦60 in the three samples. Accordingly, the average cost of milling was estimated at ₦26, 677.7. This constituted approximately 11.4% of average total cost of production. Table 52 explained the components of other cost as average cost of transportation to farms and local markets (₦8, 759.3); depreciation cost (₦2, 371.2); cost of maintenance (₦121.3), cost for green manure (₦3, 857.5) and miscellaneous cost (₦575.4).

Farm income from the sale of rice output by rice farm households in all the samples ranged between ₦30, 000.0 and ₦4, 500,000.0. Consequently, the average farm income for each rice farm was estimated at ₦454, 420.0 but varied across the state samples. A further investigation revealed that the differences in the farm incomes received for the sale of paddy and milled rice output by the groups were statistically significant as $F\,(2{,}297) = 8.2$; $p < 0.001$. Considering the average output, the farm income for a kg of rice output sold was estimated at ₦177.6 in all farms. An appraisal of the relationship between income and cost of production indicated that average farm income to average total cost ratio was 1.9 (see Table 53).

Table 53

Farm Income and Profit of Rice Farm Households

Items	Kaduna (*n*=100)	Nassarawa (*n*=100)	Niger (*n*=100)	Total (*N*=300)
	Mean	Mean	Mean	Mean
Farm income (Naira)	630,670.0	358,870.0	373,720.0	454,420.0
F statistic		8.23*		
Standard Deviation	706,406.5	327,651.0	494,543.5	545,316.2
Farm income (Naira/kg)	168.8	205.3	170.6	177.6
Total variable cost (Naira)	286,534.7	220,316.6	187,773.8	231,541.7
Total cost (Naira)	293,081.7	221,466.6	189,758.8	234,769.0
Total cost (naira/kg)	78.4	126.7	86.6	91.8
Gross margin (Naira)	344,135.3	138,533.4	185,946.2	222,878.3
Income-variable cost ratio	2.2	1.6	2.0	2.0
Income- cost ratio	2.2	1.6	2.0	1.9
Profit (Naira)	324,747.8	124,207.9	178,903.2	209,286.3
F statistic		8.39*		
Standard Deviation	477,428.8	191,907.3	360,225.2	371,238.7
Output (kg)	3737.3	1747.7	2190.3	2558.4
Gross margin (Naira/kg)	92.1	79.3	84.9	87.1
Profit (Naira/kg)	86.9	71.1	81.7	81.8

Notes. Compiled from field survey data, and * is significance level at 1%.

The average gross margin for a rice farm was derived from the average farm income less the average variable cost. Hence, the gross margin for rice farms in all the samples was ₦222, 878.3, representing a gross margin of ₦87.1 for a kg of output. Similarly, the average profit margin for all rice farms in the season when the survey was conducted was ₦209, 286.3. In terms of profit margin for kg of rice output sold in the whole samples was ₦81.8. Additional appraisal of the survey results revealed that the differences in the levels of profit margins from production of paddy rice output by the rice farm households in all the three groups were statistically significant as $F(2,297) = 5.85$; $p < 0.01$.

P**rofitability of rice production in the three samples.** In line with substantial differences in cost of production, farm income and profit margin, the analysis of the profitability of rice production across the three samples became relevant. Thus, in the remaining of the section, the operational performances of the rice farm households in the three different states samples were appraised.

First, an appraisal of the rice production profit in Kaduna State showed that the average total cost of production in each farm during the season was ₦293, 081.7. This amount implied that the cost of production of a kilogram of rice output by each farmer in the state was ₦78.4 (see Tables 64 & 66). Average total cost comprised rentals (₦6, 547.0); cost of fertilizer (₦39,673.4); cost of labor input (₦115, 150.5); cost of hiring farm tractors (₦14, 546.0); cost of herbicides (₦14,627.5); cost of insecticides (₦ 18,222.5); cost of purchase of rice seeds (₦17,305.5); milling cost (₦45,475.0); debt service payments (₦8,080.0) and other costs (₦23,800.8).

In terms of distribution of the costs of inputs, labor, fertilizer, milling and other costs accounted for 73.0% of average total costs. However, the average cost of labor input as in the case of all the samples contributed about 39.3% to the average total cost. Similarly, the average farm income to the rice farms in Kaduna State stood at ₦630, 670.0, representing ₦168.8 for a kilogram of rice output. Thus, the gross margin was estimated at ₦344, 135.3 or ₦92.1 for a kilogram of rice output produced and sold.

Accordingly, the average profit to rice farms in the state was estimated at ₦324, 747.8 thus, meaning that the profit margin for every kilogram of rice output sold was ₦86.9 (see Table 53). This was found higher than the profit margins in all other states as well as the profit margin for the whole sample.

An evaluation of the survey results of rice production profit in Nassarawa state showed that the average total cost during the season was ₦221, 466.6, indicating a cost of production of a kilogram of rice output as ₦126.7. By this, the state recorded the highest cost of production compared to the costs of production in Kaduna and Niger States. The overall average cost to each farm consisted of rentals (₦1, 150.0), cost of fertilizer (₦35,318.5), cost of labor input (₦100,766.0), cost of hiring farm tractors (₦28,600.0), cost of herbicides (₦11, 652.5), cost of insecticides (₦3,199.5), cost of purchase of rice seeds (₦18,904.6), milling cost (₦10,924.0) and other costs (₦10,621.5).

In terms of the shares of these components of cost of production, cost of labor and fertilizer inputs constituted 45.5% and 15.9%, respectively. Other major costs were use of farm tractors (12.9%); rice seeds purchased (8.5%); purchase of herbicides (5.3%) and other costs (4.9%). In comparison with the farm activities in Kaduna State, the milling cost was marginal, accounting for only 4.9% of the total cost. This was attributed to fact that most of paddy rice farm households were not engaged in milling as well as the low cost of milling in Nassarawa State. Hence, each rice farm household in the state received an average of ₦358, 870.0 as farm income from the sale of rice output. Precisely, this implied that the farms had income inflow of ₦205.3 from a kilogram of rice sold and higher than that received in Kaduna and Niger States as well as the farm income per a kg rice output in a combined sample.

Other indicators showed that the average income-cost ratio was 1.6, while gross margin from cultivation of paddy rice was ₦138, 533.4 or ₦79.3 for a kilogram of rice output produced and sold. Thus, during the cropping season, the net profit to rice farms in the state sample was ₦124, 207.9 and so this is interpreted as a net profit of ₦71.1 for a kilogram of rice output sold. This amount was the least compared to the net profits in other states as well as the overall profit in all the samples.

The survey results from Niger State also showed a similar trend in terms of cost, farm income and the operational profit as in other state samples. The average total cost during the season in Niger State was ₦189, 758.8. So, this is interpreted to mean that the actual cost of production for kilogram of rice output was estimated at ₦86.6. The average cost to each farm comprised rentals (₦1,985.0); cost of fertilizer (₦35,933.0); cost of labor input (₦57,763.0); cost of hiring farm tractors (₦21,200.0); cost of herbicides (₦21,846.0); cost of insecticides (₦1,044.0); cost of purchase of rice seeds (₦9,368.5); milling cost (₦23,634.0); and other costs (₦12,661.8).

The distribution of costs showed the shares of these components in average total cost of production. For instance, the cost of labor, fertilizer and herbicides inputs, machine labor and milling cost constituted 84.5% of the total cost, while other costs accounted for 6.8%. However, the rice farm households incurred a lower cost on purchase of rice seeds for planting, constituting only 4.9% of the total average cost. This was attributed largely to the low seed replacement as alluded earlier (see Table 54). The rice farms operations in Niger State during the survey period resulted in an average farm income of ₦373, 720.0 and so showed an average farm income of ₦177.6 from a kilogram of rice sold.

Other indicators revealed that the average income-cost ratio was 1.9 and the gross margin from farm activities was ₦185, 946.2, which was exactly ₦84.9 for a kilogram of rice output produced and sold. Thus, the farmers in the state during the cropping season made an estimated net profit of ₦178, 903.2, implying a net profit of ₦81.7 for a kilogram of rice output sold.

Efficiency Analysis of Rice Production

This section discussed the empirically estimated results of the technical, allocative and cost efficiency measures of the paddy rice farm households in the selected states in Nigeria. The estimations of the observed data used distinctively the DEA and SF approaches as explained earlier. Under the DEA approach, the standard CCR and BCC-DEA models with an input-oriented plan were employed to estimate the technical efficiency frontiers of the paddy rice farm households in the samples. Thus, the DEA model for the technical efficiency was estimated and discussed employing the CRS and VRS assumptions for the paddy rice production frontiers.

In estimating DEA cost efficiency frontier of rice farm households, only the BCC-DEA model was applied with an assumption of an input-oriented production plan. Again, evaluation of cost efficiency levels of rice farm households were conducted using the consolidated data. As such, the model used only the VRS assumption with an input-oriented production plan. Therefore, the estimation of the two DEA efficiency frontiers focused on the overall average performance (*N*=300) as well as the average state performances (*n*=100).

Thus, the analysis of the DEA models was organized as follows: first, the technical estimates under the two RTS assumptions were analyzed and subsequently, the cost efficiency estimates were also discussed. However, since the estimation of the technical efficiency scores used the two DEA models, average scale efficiency of the rice farm households was also estimated and analyzed. As a result, the average allocative efficiency score was derived as a residual of the estimated technical and cost efficiency frontiers. Overall, the DEA estimations employed the PIM-DEA Version 3.2 software for the estimations of the technical, allocative and cost efficiency frontiers.

However, the analysis with the SF approach differed as it employed regression models. First, the analysis of survey results explored the input-oriented model for the estimation of the technical efficiency frontier employing the Cobb-Douglas production function. Overall, like the DEA, the focus was on the analysis of the average overall performance as well as the average state performances. As indicated earlier, the cost efficiency frontier under the SF approach was estimated using the translog cost function with an input-oriented assumption. The estimations of the technical and cost efficiency frontiers of the paddy rice farm households in our samples under the SF approach used the STATA version 14.1 software.

DEA Technical Efficiency Analysis

The analysis of DEA technical efficiency measure of the paddy rice farm households with the CRS and VRS assumptions employed eight inputs for paddy rice production and the paddy rice output to estimate the production frontiers. The inputs include land area (fixed input) and seven other variable inputs such as: fertilizer, rice seeds, herbicides, insecticides/fungicides, labor measured in man-hour, machine use labor measured also in man-hour, and green manure applied. The descriptive statistics of these inputs and paddy rice output were previously summarized in Table 47.

Table 54 therefore showed the empirical results of the estimation of the technical efficiency scores of the selected paddy rice farmers in the three sampled states. According to the Meta frontier or overall results (combined observed production data from the field survey), the average technical efficiency under a constant returns-to-scale assumption was 0.592 or 59.2%. This score means that rice farm households should reduce inputs used for cultivation of paddy rice by 41.0% and would be able to produce the current level of paddy rice output. The minimum technical efficiency obtained by the rice farm households was 0.17 or 17.0% and the maximum was 1. In terms of the distribution of the technical efficiency scores of all the paddy rice farms around the mean, the results showed that about 52.7% of the farms had technical efficiency scores below the mean score, while 42.3% were above the average score.

Relative to the Meta frontier, the paddy rice farms technical efficiency level of 0.672 or 67.2% in Niger State was higher than that of the Meta frontier as well as the average scores of the other two states. Overall, the average technical efficiency of the paddy rice farm households in Kaduna and Nassarawa States were below the combined average at 0.56 and 0.55, respectively. Nevertheless, the Kruskal-Wallis rank test showed that the differences in the mean technical efficiency levels in the three samples were not statistical significant as χ^2 =298.60; p=0.497 (see Table 54).

Table 54

Model 1: Average Technical Efficiency Scores with a CRS Assumption

Frontiers	Mean	%	Min	Max	SD
Meta frontier (N=300)	0.59	59.19	0.17	1.00	0.24
Kaduna State frontier (n=100)	0.56	55.72	0.18	1.00	0.27
Nassarawa State frontier (n=100)	0.55	54.63	0.17	1.00	0.21
Niger State frontier (n=100)	0.67	67.22	0.32	1.00	0.20
Kruskal-Wallis rank test					
Chi-square		*298.60*			
Sig		0.497^{ns}			

Notes. Compiled from field survey data, and *ns* means not statistically significant.

The results as presented with the variable returns-to-scale assumption for the production technology for the paddy rice farms in whole sample revealed a higher technical efficiency scores (see Table 55). Thus, average technical efficiency scores was 0.721 or 72.1%, while the minimum efficiency score was 0.22 and the maximum was 1.0. The results showed disparity in the Meta frontier average technical efficiency level under VRS assumption, when compared to the average score recorded under the CRS assumption. By this result, it implies that the rice farms should reduce the inputs used by only 38.0% instead of 42.0% as indicated under the CRS assumption and would be able to attain the current level of paddy rice output.

In terms of the distribution of the scores, about 49.7% of the paddy rice farms had technical efficiency scores below the Meta frontier average score, while 50.3% had scores that were above the mean score. Again, the Niger State paddy rice farm households recorded the highest average technical efficiency level of 0.774 or 77.4% as under the CRS, while the average technical efficiency scores by Kaduna and Nassarawa States of the paddy rice farm households at 0.70 and 0.69, respectively, under the VRS assumption were below the Meta frontier average score. However, the differences in the average technical efficiency scores were similarly found not statistically significant as χ^2 =297.62; p=0.512.

Table 55

Model 2: Average Technical Efficiency Scores with a VRS Assumption

Frontiers	Mean	%	Min	Max	SD
Meta frontier (*N*=300)	0.72	72.09	0.22	1.00	0.20
Kaduna State frontier (*n*=100)	0.70	70.22	0.26	1.00	0.21
Nassarawa State frontier (*n*=100)	0.69	68.64	0.22	1.00	0.21
Niger State frontier (*n*=100)	0.77	77.41	0.39	1.00	0.17
Kruskal-Wallis rank test					
Chi-square		*297.62*			
Sig		0.512^{ns}			

Notes. Compiled from field survey data, and *ns* means not statistically significant.

In consideration of the estimated technical efficiency scores for both RTS assumptions and using equation 56, the individual farms scale efficiency scores were also calculated. Table 56 revealed that the estimated average scale efficiency of all responding farms was 0.81 or 81.4%. The minimum scale efficiency recorded in all farms sample was 0.18 or 18.0% and the maximum was 1. The distribution showed that 40.7% of the paddy rice farm households had scale efficiency scores that were below the average and 59.3% had scores also that were above the average. By implication, the results showed that the paddy rice farm households were very close to the optimum farm size.

There were also some disparities across the subsamples in the average scale efficiency scores. The farmers in Niger State had an average scale efficiency score of 0.864 or 86.4%, which was higher than the Meta frontier average and above the average scores recorded in the other two states. However, the average scale efficiency scores by Kaduna and Nassarawa States paddy rice farm households were lower than the Meta frontier average scale efficiency score. Notwithstanding the differences in the scale efficiency scores relative to the Meta frontier, the result of the Kruskal-Wallis rank test showed that the differences were also not statistically significant as χ^2 =298.53; p=0.497.

Table 56

Model 3: Average Scale Efficiency Scores

Frontiers	Mean	%	Min	Max	SD
Meta frontier (N=300)	0.81	81.42	0.18	1.00	0.19
Kaduna State frontier (n=100)	0.78	77.87	0.18	1.00	0.24
Nassarawa State frontier (n=100)	0.80	79.96	0.27	1.00	0.18
Niger State frontier (n=100)	0.86	86.42	0.52	1.00	0.13
Kruskal-Wallis rank test					
Chi-square		*298.53*			
Sig		0.497^{ns}			

Notes. Compiled from field survey data, and *ns* means not statistically significant.

DEA Economic Efficiency Analysis

In this study the cost efficiency was applied to appraise the economic efficiency levels of the farm households assuming the input-oriented production plan and also using only the VRS production assumption. In other words, the objectives of paddy rice farms were assumed to be minimizing cost of production in order to achieve the current output level of paddy rice. Simply, the cost efficiency with a DEA approach was estimated using a nonparametric cost function. Therefore, cost efficiency estimation in the PIM-DEA version 3.2 Software used the physical quantities of the input variables and output as well as the prices of the inputs. The quantities of the 8 input variables as shown earlier and the respective prices were employed to estimate the cost efficiency levels of the individual farm households.

Table 57

Model 4: Average Cost Efficiency Scores with a VRS Assumption

Frontiers	Mean	%	Min	Max	SD
Meta frontier (*N*=300)	0.30	30.0	0.09	1.00	0.15
Kaduna State frontier (*n*=100)	0.35	35.0	0.09	1.00	0.19
Nassarawa State frontier (*n*=100)	0.25	25.0	0.10	1.00	0.15
Niger State frontier (*n*=100)	0.29	29.0	0.12	0.69	0.09
Kruskal-Wallis rank test					
Chi-square		*298.99*			
Sig.		0.4982^{ns}			

Notes. Compiled from field survey data, and *ns* means not statistically significant.

The empirical results presented in Table 57 showed that the overall average cost efficiency level of the paddy rice farms for the whole sample was estimated at 0.30 or

30.0%. These results indicated that the paddy rice farmers were less cost efficient but more technically efficient in the production of paddy rice and therefore will need to reduce cost of inputs by about 70.0% and could still be capable of producing the current level of paddy rice output. Further investigations showed that only 118 or 39.3% of the 300 paddy rice farm households were operating above the Meta frontier efficiency level of 0.30, while 182 rice farm households or 60.7% were at levels below the empirical estimated average cost efficiency score.

The major reasons adduced were the over use of inputs as well as the high cost of inputs and the extreme dependence on physical labor rather than machine labor that could reduce labor cost. However, the empirical results revealed that paddy rice farm households in Kaduna State at 0.35 or 35.0% level of cost efficiency performed better compared to the whole sample average cost efficiency score. Similarly, this was higher than the average scores by the paddy rice farm households in Nassarawa and Niger States. However, additional analysis using the Kruskal-Wallis rank test showed that the differences were not statistically significant as χ^2 =298.99; p=0.498.

An additional appraisal of the efficiency level using the allocative efficiency frontier was conducted since the technical and cost efficiency scores are known. Table 58 explained the average score for the allocative efficiency of the rice farm households for the whole sample and in the individual subsamples. The empirical results confirmed that the average allocative efficiency of the whole sample was 0.39 or 39.0% (see Table 58).

Perhaps, this could be attributed to the lower average cost efficiency estimated for the paddy rice farm households.

Generally, about 59.0% of the rice farm households in the whole sample were predicted to be operating below the average score, while 41.0% were above the average. Further review of the results indicated that rice farm households in Kaduna State in terms of average allocative efficiency score performed better than the farmers in Nassarawa and Niger States. Nevertheless, the differences were found not statistically significant as the χ^2 =298.99; p=0.498.

Table 58

Model 5: Average Allocative Efficiency Scores

Frontiers	Mean	%	Min	Max	SD
Meta frontier (n=300)	0.39	38.56	0.11	1.00	0.17
Kaduna State frontier (n=100)	0.47	46.52	0.11	1.00	0.19
Nassarawa State frontier (n=100)	0.34	33.86	0.12	1.00	0.16
Niger State frontier (n=100)	0.35	35.29	0.17	0.88	0.12
Kruskal-Wallis rank test					
Chi-square		*298.99*			
Sig.		0.4982^{ns}			

Notes. Compiled from field survey data, and *ns* means not statistically significant.

SF Technical Efficiency Analysis

This section focused on the analysis of the technical efficiency of rice farm households using the parametric models (OLS/COLS and stochastic frontier models). In modeling the technical efficiency of the rice farm households using the consolidated data, it was assumed that the variable inputs are exogenously determined and the production objectives were to minimize the use of inputs. Land was however classified as fixed input and endogenous to the model, hence was dropped as an independent variable. In the technical efficiency models, the Cobb-Douglas production function was employed but the output and input variables were all transformed into their natural logarithmic forms.

Thus, in the first step, the OLS model was used to estimate the Cobb-Douglas production function for paddy rice output of the paddy rice households. The OLS model was specified as in equation 64:

$$loutput = \beta_0 + \beta_1 llabor + \beta_2 lseeds + \beta_3 lfert + \beta_4 lman + \beta_5 lherb + \beta_6 lmanure + \beta_7 lins \quad (64)$$

Where: *llabor* is the log of man-hours of farm labor; *lseeds* is the log of quantity of rice seeds in kilograms; *lfert* is the log of quantity of fertilizer in kilograms; *lman* is the log of man-hours of machine labor; *lherb* is the log of quantity of herbicides in liters; *lmanure* is the log of quantity of green manure in kilograms; and *lins* is the log of quantity of insecticides applied in liters.

The results revealed that estimated coefficients of the input variables of *llabor*, *lseeds, lfert*, *lman*, and *lmanure* were all positive at 0.77, 0.64, 0.18, 0.42, and 0.67, respectively and were significant for ps < 0.1. The results were therefore consistent with the theoretical foundation of the production frontier. However, *lins* output elasticity was negative at 0.14 but statistically significant for $p < .0001$. The coefficient for *lherb* at 0.06 was positive but was statistically not significant. These results showed that the inputs applied in the model could explain about 78.6% of the paddy rice output produced (see Table 59).

Table 59

Model 6: OLS Estimate of Technical Efficiency

Source	SS	df	MS	Number of obs	300
Model	203.738	7	29.11	$F(7, 292)$	157.38
Residual	54.003	292	0.185	Prob > F	0.0000
Total	257.741	299	0.862	R-squared	0.7905
				Adj R-squared	0.7855

Loutput	*Coef.*	*Std. Err.*	*t*	*P>|t|*	*[95% Conf. Interval]*	
Llabor	0.077	0.045	1.69	0.091	-0.012	0.166
Lseeds	0.644	0.068	9.51	0.000	0.511	0.777
Lfert	0.178	0.049	3.66	0.000	0.082	0.273
Lman	0.42	0.082	5.13	0.000	0.259	0.581
Lherb	0.056	0.051	1.1	0.272	-0.044	0.155
Lmanure	0.067	0.038	1.78	0.076	-0.007	0.141
Lins	-0.14	0.035	-4.03	0.000	-0.279	-0.072
Cons	2.003	0.371	5.4	0.000	1.273	2.733

The OLS results also showed that the sum of the coefficients of the inputs that were statistically significant indicated a production technology close to an increasing returns-to-scale (i.e. the sum of 0.077+0.64+0.18+0.42+0.07-0.14 is equal to 1.25), meaning. Following the OLS estimation, an extension of the OLS model was used to obtain the measures of technical efficiencies of the individual rice farm households in the whole sample. Specifically, COLS was applied to obtain the efficiency scores of the individual rice farm households.

The model results revealed an average technical efficiency level of 0.31 or 31.0% for rice farm households in the whole sample. While the minimum efficiency score was 0.08 (8.0%), the maximum was 1.0 (see Table 60). By this results, it simply means that the rice farm households in the sample will need to reduce the utilization of farm inputs by almost 69.0%, and could still attain the current level of paddy rice output.

Table 60

Summary of COLS Estimates of Technical Efficiency

Frontiers	Obs	Mean	SD	Min	Max
Meta	300	0.31	0.14	0.08	1.00
Kaduna State	100	0.36	0.16	0.07	1.00
Nassarawa State	100	0.25	0.11	0.09	0.65
Niger State	100	0.31	0.19	0.13	0.61
F statistic		18.53*			

Note. * means significance level at 1%.

Furthermore, Table 60 explained the differences by state subsamples generated from the COLS regression model. While Kaduna state with an average of 0.36 or 36.0% recorded the highest mean technical efficiency but Nassarawa State at 0.25 or 25.0% mean technical efficiency had the lowest. This was in contrast with the DEA estimates for both CRS and VRS assumptions. However, an ANOVA test showed that the differences across the state subsamples were statistically significant as F (2,297) = 18.53; $p < 0.001$ and again in contrast to the estimates from the DEA models.

Perhaps the high inefficiency observed in the data from the COLS estimates could be attributed to the presence of outlier(s). In other words, the OLS estimation was largely deterministic, which could have attributed all deviations to technical inefficiency. In this case, an additional estimation was conducted using the stochastic production frontier. This was intended to disentangle the composite error term into those that can be attributed to technical inefficiency and those attributed to factors beyond the control of the paddy rice producers.

However, prior to the specification of stochastic production frontier model, the residuals obtained from the OLS estimation of the production model were subjected to the *skewness test* for normality. This was to verify the validity of the stochastic frontier model specification of the observed data. From the theory, the overall skewness of the OLS residuals in this case is expected to be left-sided skewed (Schmidt & Lin, 1984). In line with this, the skewness test statistic generated from the OLS residuals should be negative and statistically significant. Thus, the null hypothesis for the skewness test for normality is that there is no skewness, while the alternative hypothesis is that there is skewness.

Table 61

OLS Residuals Test for Skewness/Kurtosis

		Model 5: OLS			
	Percentiles	Smallest			
1%	-1.08	-1.35			
5%	-0.74	-1.13			
10%	-0.52	-1.12	Obs	300	
25%	-0.29	-1.04	Sum of Wgt.	300	
50%	0.01		Mean	1.27E-10	
		Largest	Std. Dev.	0.43	
75%	0.26	0.99			
90%	0.53	1.03	Variance	0.18	
95%	0.73	1.18	Skewness	-0.002	
99%	1.01	1.28	Kurtosis	3.21	
		Skewness/Kurtosis tests for Normality			
				------ joint ------	
Variable	Obs	Pr(Skewness)	Pr(Kurtosis)	chi2(2)	Prob > chi2
Epsilon	300	0.987	0.362	0.83	0.66

Table 61 showed that the skewness test for normality statistic had a negative value of -0.002 which was not statistically significant at $p = 0.987$. Carree (2002) reported that lack of negative skewness is a common problem in the use of the stochastic production frontier analysis as most times the estimated skewness of the residuals is positive. For instance, Green and Mayes (1991) argued that, apart from possible misspecification of the production functions, positive skewness of the OLS residuals should be an indication of possible *super efficiency* (all firms in the industry are efficient) or the inappropriateness of the technique of frontier production function analysis to measure inefficiencies.

However, in this case, the results were inconclusive as such the stochastic frontier model was specified, using the Cobb-Douglas production function as negative skewness was identified but was not statistically significant. The stochastic frontier model was therefore, estimated with two key assumptions about the distribution of the one-sided error term, u_i and these were the normal half-normal input-oriented and the normal-exponential input-oriented distribution assumptions. Therefore, the stochastic model was specified as below, while the variable *lherb* was dropped following the results of the OLS:

$$loutput = \beta_0 + \beta_1 llabor + \beta_2 lseeds + \beta_3 lfert + \beta_4 lman + \beta_5 lmanure + \beta_6 lins + \mu_i - \nu_i \qquad (64)$$

The model was therefore estimated with the Maximum Likelihood Estimation (MLE) technique by maximizing the log-likelihood function and the MLE estimated parameters are provided below.

Table 62

Model 7: Technical Efficiency under Half-Normal Distribution

			Number of obs	=		300
			Wald chi2(6)	=		1001.95
Log likelihood	-169.018		Prob > chi2	=		0.000
loutput	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
frontier						
llabor	0.082	0.044	1.86	0.063	-.005	0.170
lseeds	0.665	0.063	10.54	0.000	.542	0.789
lfert	0.199	0.048	4.15	0.000	.105	0.293
lman	0.429	0.080	5.36	0.000	.272	0.586
lmanure	0.067	0.037	1.78	0.075	-.007	0.140
lins	-0.134	0.034	-3.95	0.000	-.201	-0.068
usigmas						
_cons	-2.58	1.713	-1.51	0.132	-5.938	0.777
vsigmas						
_cons	-1.876	0.313	-5.99	0.000	-2.490	-1.262

The estimated coefficients of the input variables were close to the estimates that were obtained from the OLS model shown in Table 59, while all the coefficients of the variables in the model were found to be positive and statistically significant for *p*'s < 0.1, except for *lins* that the elasticity was negative at 0.134 but statistically significant as $p < 0.1$. The output elasticity of seeds was 66.5%, which was the highest among the inputs. As in the OLS estimates, the sum of the output elasticity of all inputs included in the model, which were significant was again close to 1.31, thus indicating an increasing return-to-scale production technology. This means that a proportional increase in the vector of inputs will lead to more than proportional increase in the paddy rice output.

To confirm the presence of technical inefficiency in the model a likelihood ratio test was conducted. The null hypothesis is $\sigma^2_\mu = 0$, while the alternative hypothesis is $\sigma^2_\mu \neq 0$. The likelihood ratio derived from the estimated model was 0.1461 and the generated mixed chi-square statistic at different significance levels is shown in Table 63. The test statistic at 5% significance level was 2.705 and since it was higher than the model's test statistic, it simply implies that we failed to reject the null hypothesis meaning an outright acceptance of the null hypothesis of no technical inefficiency:

Display -2*(ll_ols - ll_h_IO) = 0.14607546

sf_mixtable, dof (1)

Table 63

Critical Values of the Mixed Chi-square Distribution

	Significance level						
dof	0.25	0.1	0.05	0.025	0.01	0.005	0.001
1	0.455	1.642	2.705	3.841	5.412	6.635	9.5

Source: Table 1, Kodde and Palm (1986, Econometrica).

However, the observation-specific efficiency scores of the individual rice farm households were estimated. The results showed that the mean technical efficiency under the half-normal distribution assumption was .81 or 81.0% (see Table 64). The implication of this result was that the SF parametric approach under normal half-normal assumption of the one-sided error term revealed that paddy rice farm households should reduce the use of inputs by only 19.3% and will still be able to attain the current level of output. This was generally contrary to the estimates generated through the DEA and the OLS models. Overall the SF model with normal half-normal distribution however scored the paddy rice farm households as super efficient as against the results generated from the DEA and OLS models.

Table 64

Technical Efficiency with Half-Normal Distribution by Sub-Samples

	Mean	*%*	*SD*	*Min*	*Max*
Meta Frontier(*N*=300)	0.81	81.00	0.05	0.59	0.91
Kaduna State(*n*=100)	0.81	81.00	0.05	0.59	0.91
Nassarawa State(*n*=100)	0.80	80.00	0.06	0.62	0.90
Niger State(*n*=100)	**0.80**	80.00	0.05	0.63	0.91
F Statistic			$1.46^{ns.}$		

Note. ns means not statistically significant

A further investigation using the subsamples revealed no specific differences across the samples. An ANOVA test comparing the means of the three independent subsamples showed that there were no statistically significant differences across the mean technical efficiency scores of rice farm households as F (2, 297) = 1.46, p = 0.233 (see Table 64). This was also in consonance with the results from the DEA models (CRS and VRS models) but differed from the results of the OLS model.

In addition, the normal-exponential distribution model with heteroscedasticity for the one-sided error term of the stochastic production frontier for the paddy rice farms was assumed. Following this assumption, an exogenous factor affecting technical inefficiency was introduced into the model. Specifically, the share of expenditure on hired labor as a percentage of total expenditure was chosen as the exogenous determinant of technical inefficiency and this was defined as comp1. As such an additional variable comp1 was introduced to represent the heterogeneous nature of rice production found across the states. The choice of this variable was considered because the results from farm income and cost analysis indicated that cost of labor constituted the highest cost for paddy rice production in Nigeria.

Table 65

Model 8: Technical Efficiency with Normal-Exponential Distribution

				Number of obs =		299
				Wald chi2(6) =		1014.83
Log likelihood	-168.647			Prob > chi2 =		0
loutput	Coef.	Std. Err.	Z	P>|z|	[95% Conf.	Interval]
frontier						
llabor	0.083	0.045	1.830	0.067	-.006	0.171
lseeds	0.665	0.063	10.530	0.000	.541	0.789
lfert	0.199	0.047	4.260	0.000	.107	0.290
lman	0.429	0.080	5.360	0.000	.272	0.586
lmanure	0.066	0.038	1.740	0.081	-.008	0.140
lins	-0.137	0.034	-4.010	0.000	-.203	-0.070
_cons	1.989	0.345	5.760	0.000	1.31	2.666
etas						
comp1	0.001	0.018	0.070	0.940	-.034	0.036
_cons	-3.891	1.481	-2.630	0.009	-6.793	-0.988
vsigmas						
_cons	-1.835	0.189	-9.720	0.000	-2.204	-1.465

Again, the results were quite similar as the coefficients were close as in the two previous models. For instance, the log-likelihood value of -168.647 was also not too different from the -169.018 obtained in model 7. Specifically, the coefficient of comp1 was 0.001 and not statistically significant. This means that the variable had no significant impact on the determination of technical inefficiency, perhaps attributed to the relevance of family labor in the paddy rice production across the sampled paddy rice farm households. Again the sum of all the coefficients of the variables was almost the same and close to 1.3, thus showing an increasing returns-to-scale production technology. All the variables were found to be statistically significant for *p*s < 0.1 (see Table 65).

The marginal effect of comp1 on unconditional E (μ) and E (ν) that is on technical inefficiency and stochastic factors were also computed notwithstanding that the variable was not statistically significant. The results implied that on the average technical inefficiency of the individual rice farm households will increase by 0.01% if there is a 1% increase in the expenditure share of labor to total expenditure in the farm.

The likelihood ratio test also further confirmed the acceptance of the null hypothesis of no technical inefficiency similar to the previous model, thus attributing all deviations from the production frontier boundary to measurement errors, noise and 'other' stochastic factors not within the control of the paddy rice farm households. Again, Table 81 showed the mixed chi-square statistic at different significance levels. Thus, the mixed chi-square test statistic at 5% significance level is 8.761 and was higher than the model's log-likelihood test statistic of 0.887. By this result we fail to reject the null hypothesis meaning an outright acceptance of no technical inefficiency:

.display -2*(ll_ols II_e) =0.88699502

Table 66

Critical Values of the Mixed Chi-square Distribution

	Significance Levels						
dof	0.25	0.1	0.05	0.025	0.01	0.005	0.001
4	4.776	7.094	8.761	10.383	12.483	14.045	17.612

Source: Table 1, Kodde and Palm (1986, Econometrica).

The results of the technical efficiency scores under the normal-exponential distribution assumption of the one-sided error also generated the individual technical efficiency scores of the paddy rice farm households as shown in the table below. The average score of the paddy rice farm households under this assumption was 0.872 or 87.2%. The minimum score was o.629 or 62.9%, while the maximum score was below the theoretical maximum of 1 at 0.937 or 93.7%. In other words, the results derived from the normal-exponential distribution assumption further scored higher technical efficiency levels of the paddy rice farms in the sample than the scores under the normal half-normal distribution assumption or the DEA and the OLS models. Thus, it ascribed to the paddy rice producers' higher efficiency levels than all previous models.

Table 67

Technical Efficiency Scores with Normal-Exponential Distribution

Variable	*Obs*	*Mean*	*Std. Dev.*	*Min*	*Max*
bc_e	299	0.872	0.041	0.629	0.937

SF Cost Efficiency Analysis

In this section, the stochastic cost frontier model was estimated by showing how technical inefficiency can be transmitted from the production function to the cost function. Thus, the focus in the subsection is the appraisal of the cost frontier assuming that the objectives of the paddy rice farm households were minimization of cost of inputs.

Similarly as in the DEA, the estimation used an input-oriented production plan for paddy rice farm households but applied the translog cost model specification as well as generated the translog terms (see Equation 60).

Table 68

Model 9: OLS Estimation of the Translog Cost Function

Source	SS	df	MS			
				Number of obs	=	300
				F(35, 264)	=	34.79
Model	125.993	35	3.599	Prob > F	=	0.000
Residual	27.315	264	0.103	R-squared	=	0.8218
				Adj R-squared	=	0.7982
Total	153.308	299	0.513	Root MSE	=	0.32166

ltcD	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Lyi	1.42	1.40	1.02	0.309	-1.326	4.173
lyi2	0.13	0.04	3.30	0.001*	0.053	0.209
lpfD	0.89	9.38	0.10	0.924	-17.585	19.369
lpsD	0.38	3.44	0.11	0.912	-6.387	7.144
lplD	6.65	4.03	1.65	0.100***	-1.283	14.584
lpiD	-10.87	8.10	-1.34	0.181	-26.820	5.089
lpmD	-1.73	1.77	-0.98	0.328	-5.212	1.746
lpuD	16.45	17.81	0.92	0.356	-18.615	51.518
lpfD2	-0.89	1.84	-0.48	0.628	-4.513	2.730
lpsD2	-0.15	0.37	-0.41	0.685	-0.883	0.580
lpiD2	1.57	1.29	1.21	0.226	-0.976	4.113
lplD2	0.07	0.39	0.18	0.859	-0.698	0.837
lpmD2	0.16	0.07	2.30	0.022**	0.023	0.302
lpuD2	6.33	5.59	1.13	0.259	-4.678	17.330
lpfsD	0.82	0.51	1.60	0.110	-0.187	1.820
lpflD	1.86	0.82	2.28	0.023**	0.255	3.473
lpfmD	0.19	0.30	0.64	0.522	-0.395	0.775
lpfiD	-1.95	1.97	-0.99	0.323	-5.823	1.926
lpfuD	-1.32	2.89	-0.46	0.649	-7.005	4.370
lpslD	-0.18	0.27	-0.65	0.516	-0.718	0.361
lpsmD	0.05	0.12	0.43	0.665	-0.183	0.287
lpsiD	0.54	0.67	0.81	0.420	-0.784	1.873
lpsuD	-0.45	0.98	-0.46	0.649	-2.373	1.482
lplmD	-0.22	0.10	-2.33	0.021**	-0.414	-0.035
lpliD	-0.59	0.62	-0.94	0.347	-1.810	0.639
lpluD	0.05	1.39	0.03	0.974	-2.688	2.780
lpmiD	0.28	0.33	0.84	0.400	-0.370	0.926
lpmuD	-0.35	0.51	-0.69	0.489	-1.346	0.645
lpiuD	-1.48	2.45	-0.60	0.546	-6.293	3.339
lyilpfD	-0.36	0.29	-1.27	0.206	-0.929	0.201
lyilpsD	-0.06	0.09	-0.61	0.544	-0.237	0.125
lyilpiD	-0.18	0.26	-0.70	0.485	-0.688	0.327
lyilplD	-0.11	0.08	-1.32	0.188	-0.271	0.053
lyilpmD	0.06	0.03	1.89	0.060***	-0.003	0.129
lyilpuD	0.83	0.40	2.11	0.036**	0.055	1.611
_cons	44.82	33.86	1.32	0.187	-21.854	111.496

By construction, the model satisfies the price homogeneity condition. First, in the OLS model estimated, of the 35 variables only seven variables were found statistically significant at 1%, 5% and 10% levels of significance. Again, the variables in the model explained about 78.9% of the variations in total cost of paddy rice production. Unfortunately, all own price elasticities were found not statistically significant, except the price of labor and machine hiring price per hour for ps < 0.1. The cross price elasticities of labor and fertilizer, and labor and machine were found statistically significant for ps < 0.05 (see Table 68).

An extension of the OLS that is COLS was used to obtain the individual specific cost efficiency levels. The COLS model results indicated that, on the average, the rice farm households achieved a cost efficiency level of 0.467 or 46.7%, while the minimum efficiency score was 0.159 (15.9%) and the maximum was 1 (see Table 69). By these results it means that the rice farm households will need to reduce the cost of production of paddy rice by reducing the amount of farm inputs utilized by almost 53.3%, and will still be capable of producing the current level of paddy rice output.

Also, Table 69 showed the average cost efficiency by state samples. The results revealed that Kaduna State with an average of 0.522 or 52.2% recorded the highest mean cost efficiency above the overall mean score as the same in the DEA. On the contrary, Nassarawa State at 0.435 or 43.5% mean cost efficiency had the lowest. An ANOVA analysis showed that the differences across the state samples were statistically significant as F (2,297) = 12.45; $p < 0.001$.

Table 69

COLS Estimates of Cost Efficiency of the Rice Farm Households in the Sample

	COLS				
	Mean	%	Min	Max	SD
Meta frontier(*N*=300)	0.467	46.7	0.159	1.000	0.141
Kaduna State (*n*=100)	0.522	52.20	0.214	1.000	0.161
Nassarawa State (*n*=100)	0.435	43.50	0.120	0.876	0.135
Niger State (*n*=100)	0.445	44.50	0.159	0.724	0.105
F Statistic			12.45*		

Note: * is significance level at 1%.

Again, since the OLS estimation was largely deterministic attributing all deviations to cost inefficiency, an additional estimation was conducted using the stochastic cost frontier. However, prior to the specification of stochastic cost frontier model, the residuals obtained from the OLS model were subjected to the skewness test for normality (see Table 70). This was specifically to verify the validity of the stochastic cost frontier model specification of the observed cost data. According to theory, the overall skewness of the OLS residuals under the cost frontier is expected to have a right-sided skewness for the cost efficiency frontier (Schmidt & Lin, 1984).

Table 70 showed that the skewness test statistic had a positive value of 0.185674 but not statistically significant for $p > 0.05$. The results was again inconclusive therefore, the stochastic cost frontier model with translog cost function was specified (see equation 60).

Table 70

OLS Model 8 Residuals Test for Skewness/Kurtosis

summarize epsilon,	detail /* skewness should be Residuals	positive */	
Percentiles	Smallest		
1% -.6574479	-0.80543		
5% -.4878989	-0.67304		
10% -.3819756	-.6681669 Obs		300
25% -.1993144	-.6467289 Sum of wgt.		300
50% -.0030735	Mean		2.66E-10
	Largest Std. Dev.		0.302249
75% .1828511	0.727286		
90% .3802201	.7375937 Variance		0.091355
95% .4926432	.8046833 Skewness		0.185674
99% .7324397	1.029941 Kurtosis		3.114788

Skewness/Kurtosis tests for Normality

Variable	Obs	Pr(Skewness)	Pr(Kurtosis)	------ joint ------ chi2(2)	Prob>chi2
Epsilon	300	0.1824	0.5497	2.14	0.3437

The stochastic frontier was therefore, specified for only half-normal input-oriented distribution with heteroscedasticity. Again, the same variable comp1 as in model 8 was adopted to represent the heteroscedasticity variable in the model. The variable p_h representing the price of herbicides for the i^{th} producer was used to normalize the total cost and other input prices of observation i in the equation, while the translog terms were also generated for the model as in the case of the OLS model.

Table 71

Model 9: Estimation of the Translog Cost Function

					Number of obs =	300
					Wald chi2(35 =	1793.74
Log likelihood	-15.5308				Prob > chi2 =	0.000
ltcD	Coef.	Std. Err.	Z	P>|z|	[95% Conf.	Interval]
Frontier						
lyi	1.42	1.222	1.16	0.247	-0.979	3.811
lyi2	0.12	0.034	3.63	0.000*	0.057	0.190
lpfD	14.68	8.803	1.67	0.095***	-2.570	31.936
lpsD	1.29	3.155	0.41	0.683	-4.895	7.474
lplD	1.78	3.302	0.54	0.591	-4.695	8.248
lpiD	-6.65	7.111	-0.94	0.350	-20.586	7.287
lpmD	-3.47	1.481	-2.34	0.019**	-6.368	-0.562
lpuD	-1.55	15.636	-0.1	0.921	-32.200	29.092
lpfD2	-0.79	1.555	-0.51	0.612	-3.837	2.258
lpsD2	-0.20	0.299	-0.68	0.495	-0.790	0.382
lpiD2	0.50	1.131	0.45	0.656	-1.713	2.720
lplD2	-0.01	0.314	-0.05	0.963	-0.631	0.601
lpmD2	0.13	0.056	2.4	0.016**	0.025	0.244
lpuD2	-0.96	5.051	-0.19	0.849	-10.859	8.941
lpfsD	0.91	0.412	2.2	0.028**	0.098	1.712
lpflD	1.39	0.677	2.05	0.040**	0.061	2.716
lpfmD	-0.04	0.231	-0.16	0.871	-0.490	0.415
lpfiD	-4.31	2.017	-2.14	0.033**	-8.263	-0.357
lpfuD	2.99	2.640	1.13	0.258	-2.187	8.160
lpslD	-0.01	0.225	-0.03	0.977	-0.447	0.434
lpsmD	0.17	0.095	1.77	0.076***	-0.018	0.355
lpsiD	0.61	0.689	0.88	0.379	-0.745	1.958
lpsuD	-0.59	0.881	-0.66	0.507	-2.313	1.143
lplmD	-0.20	0.074	-2.73	0.006*	-0.347	-0.057
lpliD	-0.02	0.597	-0.03	0.972	-1.192	1.150
lpluD	-0.67	1.124	-0.59	0.552	-2.871	1.534
lpmiD	0.83	0.291	2.84	0.005*	0.256	1.397
lpmuD	-0.79	0.412	-1.91	0.057***	-1.594	0.022
lpiuD	0.67	2.456	0.27	0.786	-4.147	5.480
lyilpfD	0.15	0.256	0.59	0.553	-0.350	0.654
lyilpsD	-0.19	0.079	-2.44	0.015**	-0.345	-0.038
lyilpiD	-0.27	0.248	-1.08	0.282	-0.754	0.220
lyilplD	-0.04	0.070	-0.53	0.593	-0.174	0.099
lyilpmD	0.03	0.026	1.01	0.313	-0.025	0.078
lyilpuD	0.51	0.357	1.43	0.152	-0.189	1.212
_cons	21.81	28.451	0.77	0.443	-33.953	77.572
Usigmas						
Comp1	0.11	0.020	5.47	0.000	0.070	0.147
_cons	-7.88	1.275	-6.18	0.000	-10.374	-5.378
Vsigmas						
_cons	-2.98	0.116	-25.72	0.000	-3.203	-2.749

The results of the estimated model are shown in Table 71, while the coefficient of variable comp1, representing the heterogeneous nature of the rice farm households was found significant with a coefficient of 0.11 for $p < .001$. The coefficients of the variables in the half-normal distribution assumption were also quite close to the coefficients generated by the OLS model. However, more of the variables numbering about 12 were found statistically significant at 1%, 5% and 10% levels of significance. For instance, the own price elasticity of machine hire per man-hour had the appropriate negative sign and statistically significant for $p < .05$, indicating that a decline in the price of machine hiring per man-hour will lead to a decline in total cost of production by paddy rice farm households. Similarly, the cross price elasticity between fertilizer and rice seeds, fertilizer and labor, fertilizer and insecticides, seeds and machine, labor and machine, machine and green manure were found statistically significant.

The likelihood ratio test was conducted and the likelihood ratio test statistic of the model was given as 101.39792. Table 88 showed the critical values of the statistic at $p < 0.001$ as 12.81, which was found to be lower than the model test statistic of 101.397. The result implied a rejection of the null hypothesis of no cost inefficiency:

display -2*(ll_ols-ll_h) = 101.39792

Table 72

Critical Values of the Mixed Chi-square

	significance level						
dof	0.25	0.1	0.05	0.025	0.01	0.005	0.001
2	2.09	3.808	5.138	6.483	8.273	9.634	12.81

Source: Table 1, Kodde and Palm (1986, Econometrica).

Following the rejection of the null hypothesis, the cost efficiency scores of the individual paddy rice farm households were constructed.

Table 73

Estimate of Stochastic Cost Efficiency Scores

Variable	Obs	Mean	Std. Dev.	Min	Max
bc_h	300	0.863	0.134	0.281	0.986

As shown in Table 73, the average cost efficiency score of the rice farm households in the whole sample was 0.863 or 86.3%, while the minimum and maximum scores were 0.281 and 0.986, respectively. By implication under the half-normal with heteroscedasticity, the rice farm households will need to reduce cost of production by 13.7% and will still be capable of attaining the current level of paddy rice output.

Conclusion

The chapter gave detailed explanations of the empirical results through an analysis of the data obtained from the fieldwork. Essentially, it discussed data analytical framework that was employed to evaluate the primary data and procedures of analysis of data. The chapter highlighted and analyzed the summary statistics of data collected describing the major characteristics of the paddy rice farms households, farmers, farm management practices and production activities in the three states. In addition, it estimated profitability levels as well as technical, allocative and cost efficiency measures of paddy rice production in Nigeria using the samples from three selected states in which the survey was conducted.

Relevant statistical tests such as descriptive statistic and parametric and nonparametric statistical tests like the Independent ANOVA and Kruskal-Wallis rank tests were used to explain the variations in the primary data. Profitability analysis was conducted using farm income from paddy and milled rice sales and the cost of inputs and other costs. The estimations of the technical, allocative and cost efficiency scores of the paddy rice farm households in the samples were conducted using two distinct approaches namely the DEA and SF. In estimating the technical efficiency using the DEA, two models were specified such as the CCR-DEA and the BCC-DEA models. Thus, the estimations were conducted using the constant return-to-scale and the variable return-to-scale assumptions for the paddy rice production technologies with an input-orientation for the paddy rice farm households. Equally, the scale efficiency was estimated using the estimates of the CRS and VRS models. In estimating the cost efficiency of the observed data only the variable return-to-scale was applied.

With the SF estimations, the technical efficiency scores were estimated using the OLS/COLS, normal half-normal and normal-exponential distribution assumptions of the one-sided error term. Thus, the stochastic technical efficiency model for the paddy rice farm households was specified as Cobb-Douglas production function. However, in estimating the stochastic cost efficiency model it was specified as the translog cost function.

The summary of the results of the data analysis indicated that rice cultivation was the main occupation of majority of sampled households as well as the major important activity amongst all daily activities. The key objective of paddy rice production in the sampled states was largely semi commercial that is producing and milling paddy rice for home consumption and sale of the surplus in the local market. Evidence showed that membership of cooperative societies by paddy rice farm households was low. The paddy rice farmers in the sampled states were found to be small holders and also relied much on family labor.

The results further indicated that ownership of important farm assets for rice cultivation was low in all the subsamples, while only marginal number of farmers was able to obtain credits, which has remained a major hindrance on paddy rice production. In case of farmers' characteristics, the results showed that majority of the heads of rice farm households were male and none of the producing households owned any processing mills. Thus, those who engaged in milling of rice have relied solely on contract millers who are fragmented and usually extract exorbitant charges from the farmers. The mean years of experience with paddy rice cultivation was estimated at 9.2 years, while the average distance between homes of the farmers and the local market was moderate compared to the distance between homes and the farms. A large number of the farmers owned storage facilities but were mainly traditional storage facilities, which added no value to technical efficiency.

The data analysis further revealed that irrigation facilities was near absence in the sampled states as such most the farmers have relied on rain fed cultivation. In this circumstance, almost all the paddy farmers in the samples harvested rice during the 2014/2015 only once. Notwithstanding using family labor, the analysis of the observed data confirmed that all respondents engaged paid labor in the farms mainly for preparation of land and harvesting of paddy rice product in the absence of farm mechanization.

Generally, it was exposed that the paddy rice farm households grew both improved rice seeds but more of the traditional rice seeds with consequences of low yields. The major sources of procuring rice seeds for the period under consideration were government and the local market. All farmers in the three samples were found to have applied chemical fertilizer for rice production. Two common fertilizer used were the NPK and the Urea and majority of them procured the chemical fertilizer from government sources.

Overall, the analysis of income and cost of production showed that paddy rice production in Nigeria was marginally profitable. However, the farmers could gain more if the technical, allocative and economic efficiency scores can be improved upon through deliberate government policies. However, the results using the DEA and SF approaches produced different results in terms of the technical, allocative and cost efficiency levels of the paddy rice farm households in the samples. To complement the SF regression based estimators, the OLS and its extension of COLS were used to estimate the technical and cost efficiency scores of our sampled rice farm households. The results obtained through the COLS were also found to be more conservative, attributing high technical and cost inefficiency levels in paddy rice production in the sampled states. In essence, these levels of inefficiency need to be addressed by government in line with an earlier assertion showing the relationships between efficiency improvement, output expansion, economic growth and the general welfare of the citizens.

Chapter 5 addresses these issues of low technical and cost efficiency associated with the rice farmers in Nigeria. Thus, it highlights the relevance of the policies initiated by all tiers of government to tackle the menace of local rice supply deficiency, interprets the results, makes recommendations based on the findings so far and generally, concludes the dissertation.

Chapter 5: Discussions of Results

Introduction

This chapter discusses the final results of this study of the estimated profitability of paddy rice production and the technical and cost efficiency scores as well as the impact of public policies on the efficiency scores by paddy rice farm households in Nigeria. In Section 1, the discussion focuses on the evaluation of the outcomes of profitability analysis and discussions of major constraints hampering higher profit from the paddy rice cultivation business. The issues surrounding technical and cost efficiency are also highlighted as some of the constraints. Section 2 discusses the comparative analysis of the technical, allocative, and cost efficiency estimates by the paddy rice farm households in the samples as generated by nonparametric technique (DEA) and the parametric techniques (OLS/COLS and SF). In this evaluation, a comparative analysis is made across the various technical and cost efficiency estimates using correlation matrix and Kendall rank correlation coefficient to conduct nonparametric test of hypothesis.

Section 3 addresses the impact of policies on the selected technical and cost efficiency scores. A typical policy evaluation in randomized field experiments in development economics examines entities exposed to the policy and those that are not exposed in order to draw causal inferences regarding the effects of policies and programs (Imai, Tingley, & Yamamoto, 2013). In this study, the information provided by the respondents on whether they benefited from the input subsidy policies or not was used to evaluate the impact of policies.

I also used the DEA-generated scores to evaluate the impact of policies on the technical and cost efficiency scores. Overall, the different policies considered were access to: subsidized fertilizer, improved rice seed, herbicides/insecticides, machine hiring services, and extension services. The socioeconomic factors also considered in the models were age, membership of cooperative society and ownership of storage facilities for the impact of policies on technical efficiency. In estimating the impact of policies on cost efficiency estimates, the socioeconomic factors used were: experience, distance to market from homes, farm size, and ownership of storage facilities. Section 4 provides a critical assessment and interpretations of the findings, and after which Section 5 presents the study recommendations. Section 6 highlights the summary and conclusions.

Review of Profitability Analysis of Paddy Rice Production Business

The major source of study participants' farm income was the sale of harvested paddy and milled rice. The total gross margin per kg of rice was ₦87.1, while the final profit per kg of rice produced was ₦81.8 (see Table 53). This showed that these farmers made short-run profits at the time of the study. In dollar terms, however, using the official rate of ₦197/$1.0, the net profit was only $0.44 per kilogram of rice produced; this was significantly lower than the approximately $0.79 made by farmers in other countries such as Vietnam (Hoang & Yabe, 2012). These results suggest that the rice farm households who participated in the study spent more on inputs per kilogram of paddy rice produced than their counterparts in other countries. These findings aligned with Agbamu and Fabusoro's (2001) conclusions.

The low returns in rice production among the Nigeria rice farmers indicate that two conditions of rice production are prevalent in the country. First, these returns suggest that Nigerian rice farmers are not getting necessary inputs like improved rice seeds, improved management practices, and relevant extension services to make their business more profitable. Second, these returns imply that these farmers are not utilizing current production resources effectively so as to enhance their profits by reducing production costs. In the light of these conditions, it is important to re-examine the constraints that explained low returns from the business and understand the extent to which these factors explain loss of profit.

The results from the fieldwork indicated that among the major constraints was the high cost of labor, constituting about 38.9% of total cost for the whole sample (see Table 51). This was even higher in Nassarawa State, where the cost of labor as a total cost of production was 45.5%, significantly impacting profit margins. Consequently, this state reported the lowest profit margin among all the states' samples, with a kilogram of rice produced at ₦71.1 or $0.36. The major reason attributed to high share of cost of labor as percentage of total cost was the high wage paid to hired labor per day, which averaged about ₦856.2 or $4.4. These findings were also in consonance with Nwike and Ugwumba (2015). The high average cost of labor could be attributed to scarcity of young workers in these rural areas due to rural-urban drift.

Another major constraint that the paddy rice farmers had to tackle was the postharvest losses in terms of rice quantity and the poor quality of milled rice. As indicated earlier, the farmers were faced with harsh conditions during milling, including: constant breakdown of milling plants, high cost of milling, inadequate milling and processing facilities, and breakage of rice seeds during processing. These conditions had led to losses in terms of the quantity and quality of paddy and milled rice sold thus, contributed to substantial profit gaps among farmers (see Table 49).

Other constraints identified were the inadequate supply of inputs to support paddy rice production. The average fertilizer consumption per hectare of rice field reported by study respondents was an estimated 281.1 kg. This comprised of 220.2 kg per hectare of NPK and 55.5 kg per hectare of Urea (see Table 59). However, the average consumption by the rice farmers in the sample was still far below the recommended fertilizer rate as proposed under the rice transformation project by the Federal Ministry of Agriculture and Rural Development of 300 kg for NPK and 200 kg for Urea per hectare (FMARD, 2012).

In addition, the near absence of rice irrigation facilities in all the sampled states had implications for low returns on paddy rice cultivation. The generality of the farmers only harvested rice crops once a cropping season. Therefore, it means that the farmers are not utilizing the land resources effectively. Moreover, the existing irrigation facilities were inadequate, poorly maintained and virtually abandoned. Also, the Rural Development Departments at all levels of government are not adequately mobilized to build and maintain rural infrastructure and standard market infrastructure to support the paddy rice farmers.

Other constraints include poor extension services, low credit to rice farmers and inadequate farm machineries. Thus, profitability level of rice farm households in the samples would have been higher but for the constraints such as pest and disease problem, lack and nonacceptance of improved seeds, poor technology base and poor product price. One major conclusion that emerged from this analysis was that these constraints affected the levels of profitability of paddy rice farm households through their negative effects on technical and cost efficiency, leading to low profit efficiency.

Comparative Analysis of the Estimates of Technical and Cost Efficiencies

The results of the estimations conducted on the technical and cost efficiency measures of the paddy rice farm households are comprehensively presented in this subsection. Table 74 shows the average scores of the technical and cost efficiency measures estimated by parametric techniques (OLS/COLS, and the SF), and the nonparametric technique (DEA).

The results showed that the DEA estimates of technical efficiency for CRS and VRS were 0.592 and 0.721, respectively, when compared with the estimates of 0.313, 0.807 and 0.872 for OLS, stochastic production frontiers with normal half-normal and normal-exponential distribution assumptions of technical inefficiency, respectively. Apart from the stochastic production frontiers with normal half-normal and normal-exponential distribution assumptions of technical inefficiency, the DEA and OLS estimates recorded the theoretical maximum efficiency of 1.000.

Table 74

Summary Statistic of Estimates of TE and CE

Variable	Obs	Mean	SD	Min	Max
Technical Efficiency Scores					
Model 1: DEA_teCRS	300	0.592	0.237	0.174	1.000
Model 2: DEA_teVRS	300	0.721	0.201	0.219	1.000
Model 4: eff_colste	300	0.313	0.140	0.077	1.000
Model 5: bc_h_te	300	0.807	0.053	0.588	0.910
Model 6: bc_ete	300	0.872	0.041	0.629	0.937
Cost Efficiency Scores					
Model 3: DEA_ce	300	0.295	0.153	0.085	1.000
Model 7: eff_colsce	300	0.467	0.141	0.160	1.000
Model 8: bc_hce	300	0.863	0.134	0.281	0.986

Note. Derived from the estimates by various approaches.

In terms of cost efficiency, the DEA estimate based on the VRS assumption showed an average cost efficiency level of the paddy rice farm households of 0.295, while the OLS estimate of average cost efficiency was 0.467. Similarly, the estimates of the DEA and OLS recorded a maximum cost efficiency scores of 1.000. On the contrary, the stochastic cost efficiency estimate under the normal half-normal assumption of the distribution of the cost inefficiency term was higher at 0.863, while the maximum cost efficiency was less than the theoretical maximum of 1.000 and the minimum score was 0.281 (Table 74).

Table 75

Correlation Matrix of Estimates of Technical and Cost Efficiency Scores

TE Estimates	DEA_~CRS	DEA_~VRS	eff_c~te	bc_h_te	bc_ete
DEA_teCRS	1.0000				
DEA_teVRS	0.8152	1.0000			
eff_colste	0.0482	0.0655	1.0000		
bc_h_te	0.0186	0.0627	0.8674	1.0000	
bc_ete	0.012	0.0616	0.7889	0.9829	1.0000

CE Estimates	DEA_ce	eff_c~ce	bc_hce
DEA_ce	1.0000		
eff_colsce	0.5995	1.0000	
bc_hce	0.3278	0.6076	1.0000

Furthermore, the correlation matrix was generated for the estimates of technical and cost efficiency from the different models. The results revealed that basically there was no relationship between the nonparametric estimates and the regression-based estimates of technical efficiency scores as *rho* was less than 0.1. However, significant relationship was established between the estimates of regression-based techniques as *rho* ranged from 0.79 to 0.98. In terms of estimates of cost efficiency, statistically significant relationship was established between all the estimates. However, the correlation coefficient between the stochastic cost efficiency with normal half-normal distribution and the DEA average scores was found low but statistically significant as $p < .001$ (see Table 75). All the correlation coefficients in the matrix were positive.

Table 76

Kendall Rank Correlation Coefficients across Blocks of TE Estimates

ktau DEA_teCRS DEA_teVRS	ktau DEA_teVRS eff_colste
Number of obs = 300	Number of obs = 300
Kendall's tau-a = 0.6324	Kendall's tau-a = 0.0513
Kendall's tau-b = 0.6455	Kendall's tau-b = 0.0521
Kendall's score = 28365	Kendall's score = 2302
SE of score = 1731.014 (corrected for ties)	SE of score = 1732.227 (corrected for ties)
Test of Ho: DEA_teCRS and DEA_teVRS are independent	Test of Ho: DEA_teVRS and eff_colste are independent
Prob > |z| = 0.0000 (continuity corrected)	Prob > |z| = 0.1841 (continuity corrected)

ktau DEA_teVRS bc_h_te	. ktau DEA_teVRS bc_ete
Number of obs = 300	Number of obs = 300
Kendall's tau-a = 0.0504	Kendall's tau-a = 0.0505
Kendall's tau-b = 0.0511	Kendall's tau-b = 0.0512
Kendall's score = 2260	Kendall's score = 2266
SE of score = 1732.227 (corrected for ties)	SE of score = 1732.227 (corrected for ties)
Test of Ho: DEA_teVRS and bc_h_te are independent	Test of Ho: DEA_teVRS and bc_ete are independent
Prob > |z| = 0.1922 (continuity corrected)	Prob > |z| = 0.1910 (continuity corrected)

The results shown in Table 76 revealed the ranking between DEA_teCRS and DEA_teVRS and showed that the two estimates were not statistically independent. The calculated *p* value was less than the .05 significance level for a two-tailed test. Hence, we reject the null hypothesis that the estimates were statistically independent. Thus, the technical efficiency estimates from the DEA approach are dependent on one another and positive, indicating a positive correlation. However, in comparison with the estimates of the regression-based models (bc_h_te, eff_colste and bc-ete), the results showed the calculated *p* value > .05 for a two-tailed test. Hence, we fail to reject the null hypothesis that the estimates from the two techniques were statistically independent.

Table 77

Kendall Rank Correlation Coefficients across Blocks of CE Estimates

ktau DEA_ce eff_colsce	. ktau DEA_ce bc_hce
Number of obs = 300	Number of obs = 300
Kendall's tau-a = 0.4468	Kendall's tau-a = 0.3144
Kendall's tau-b = 0.4469	Kendall's tau-b = 0.3145
Kendall's score = 20037	Kendall's score = 14101
SE of score = 1736.344 (corrected for ties)	SE of score = 1736.344 (corrected for ties)
Test of Ho: DEA_ce and eff_colsce are independent	Test of Ho: DEA_ce and bc_hce are independent
Prob > |z| = 0.0000 (continuity corrected)	Prob > |z| = 0.0000 (continuity corrected)

Similarly, Table 77 shows the ranking of the cost efficiency estimates from the two techniques. The estimates evaluated were DEA_ce, eff_colsce and bc_hce representing estimates of cost efficiency from the DEA approach, the OLS and stochastic cost function with normal half-normal distribution approaches, respectively. The results confirmed that the estimates were statistically not independent. Hence, the calculated *p* values were all < .05 for a two-tailed test. Thus, we reject the null hypothesis that the estimates were statistically independent.

Following the observed statistical analysis and tests, we can convincingly agree that the DEA estimates of technical and cost efficiency estimates that were generated are moderately conservative and reliable as the true mean technical and cost efficiency scores by the paddy rice farm households in our samples. Moreover, the estimates from the stochastic model specifications were more generous and tended to ascribe to the paddy rice farm households as super efficient. In the light of these observations, the DEA generated estimates were used to evaluate the impact of rice subsector policy actions by all tiers of government, while controlling for specific socioeconomic characteristics associated with the rice farm households.

Impact of Policies on Rice Farm Households Efficiency Levels

The assessments of the effects of government policies on technical and cost efficiency scores of the rice farm households in the samples were conducted using the fractional regression models. The tests for the joint significance of the independent variables on technical and cost efficiency scores were also validated using the Wald Test. The technical efficiency model specifications underscored the relationships between technical efficiency [DEA_teVRS] generated by the DEA assuming a variable return-to-scale and policy variables such as access to: government subsidized fertilizer (Fert_access), government subsidized rice seeds for planting (Seed_access), government subsidized herbicides/insecticides (Hebr_access), government tractor hiring services (Mach_access), and the number of times rice farmers were visited by government appointed extension agents (Ext_times).

The use of these policy variables was an understanding that access to cheap paddy rice farm inputs enhances the technical efficiency levels of rice farm households. Data on access to these subsidized inputs were obtained from the answers given by the respondents on the sources of obtaining these inputs. As indicated previously the two major sources of access to paddy rice farm inputs were the government agency and the local markets. Thus, access to government subsidized input through the ADPs government agencies was scored 1, while purchasing input from the local markets means no access and was scored 0.

The policy factors were however, controlled by specific socioeconomic characteristics of the individual rice farmers that were: age of the head of household (Age), membership of any cooperative societies (Coop), and ownership of rice storage facilities (Ownership_storage). As shown in Table 78, the iteration log for the technical efficiency model indicated fast convergence in 3 iterations, reflecting the absence of multicollinearity in the model specification.

Table 78

Model 10: Estimated Impact of Policies on TE Scores

Iteration 0: log pseudo likelihood =	-177.131					
Iteration 1: log pseudo likelihood =	-171.649					
Iteration 2: log pseudo likelihood =	-171.639					
Iteration 3: log pseudo likelihood =	-171.639					
Fractional logistic regression		Number of obs	=	300		
		Wald chi2(9)	=	76.69		
		Prob > chi2	=	0.000		
Log pseudo likelihood	-171.639	Pseudo R2	=	0.033 7		
DEA_teVRS	Coef.	Robust Std. Err.	Z	P>|z|	[95% Conf.	Interval]
Fert_access	0.48	0.143	3.3	0.001	0.197	0.759
Seed_access	0.07	0.125	0.54	0.591	-0.177	0.311
Hebr_access	-0.20	0.158	1.24	0.214	-0.504	0.113
Mach_access	-0.30	0.065	-4.60	0.000	-0.425	-0.171
Ext_times	0.08	0.053	1.43	0.153	-0.028	0.180
Age	-0.02	0.005	-3.46	0.001	-0.029	-0.008
Coop	0.10	0.121	0.80	0.426	-0.140	0.333
Ownership_storage	-0.32	0.115	-2.70	0.005	-0.545	-0.096
_cons	1.72	0.294	5.86	0.000	1.144	2.295

These results revealed that Fert_access with a coefficient of 0.48 was positive and was statistically significant for $p < 0.01$, thus satisfying a prior expectation. This implies that as access to subsidized fertilizer increase, the immediate impact on technical efficiency of paddy rice farms is positive. However, Seed_access and Ext_times with coefficients of 0.07 and 0.08, respectively showed positive impact on paddy rice farm households' technical efficiency levels however, were statistically not significant for $p > 0.05$. Surprisingly, Hebr_access recorded a coefficient of 0.2, which was negative and not statistically significant. Mach_access was found to have statistical significant impact on technical efficiency however, showed a coefficient of 0.3 that was negative contrary to a prior expectation. Perhaps, the negative effects of Hebr_access and Mach_access could be attributed to low priority attached by government on the procurement and distribution of subsidized herbicides/insecticides and lack of access to government subsidized tractor hiring services by majority of the paddy rice farm households in the sample states.

Controlling for the impact of policy factors, age had a negative coefficient of 0.02 which and was statistically significant, according to a prior expectation. This is interpreted to mean that age of the head of the farm households was a strong determinant of the level of technical efficiency. As such technical efficiency declines as the head of the farm households grows older. Memberships of cooperative societies was found to have the appropriate positive impact but was not statistically significant. Put differently, lack of interest and patronage of rice farmers to cooperative societies could be held responsible for the results. Again, contrary to a prior expectation, ownership of storage facilities with a coefficient of 0.30 showed a negative impact on technical efficiency of paddy rice farm households however, it was statistically significant. Again, the absence of standard and modern storage facilities could have contributed to the negative effect. As indicated in the previous chapter from the field data, most of the farm households in all the samples owned largely traditional silos for the storage of paddy and milled rice with some negative consequences on technical efficiency and output.

The Wald Test on the coefficients of the variables was conducted to determine the joint significance of all these variables in model 10. Hence, the null hypothesis is stated that the coefficients of all variables in the model are set to zero. Alternative hypothesis stated that at least some are nonzero. The results of the Wald Test are presented below.

```
.test
(1)    [DEA_teVRS] Fert_access = 0
(2)    [DEA_teVRS] Seed_access = 0
(3)    [DEA_teVRS] Hebr_access = 0
(4)    [DEA_teVRS] Mach_access = 0
(5)    [DEA_teVRS] Ext_times = 0
(6)    [DEA_teVRS] Age = 0
(7)    [DEA_teVRS] Coop = 0
(8)    [DEA_teVRS] Ownership_storage = 0
chi2 (8) =   76.65
Prob > chi2 =     0.0000
```

The χ^2 p value was less than 1% of α hence I can reject the null hypothesis with confidence that at least some variables in the model were significant. Therefore, we can conveniently conclude that jointly the variables in the model have joint effect on the level of technical efficiency of the rice farm households. This means that the variables in the model jointly explained to a large extent the variations in technical efficiency levels across the paddy rice farm households.

Table 79 presents returned results on the elascticities of the covariates in model 10. The elascticities are interpreted as follows: that 1% increase in access to: government subsidized fertilizer, government subsidized and improved rice seeds, and the number of times paddy rice farmers are visited by government appointed extension agents will lead to an increase of 0.07%, 0.01%, and 0.03%, respectively in the technical efficiency levels of the paddy rice farm households. Conversely, a 1% increase in access to: government subsidized herbicides/insecticides, and government subsidized tractors and others will lead to a decline of 0.01 and 0.06, respectively in the technical efficiency of the paddy rice farm households. Similarly, I% increase in the age of the head of the rice farm household will cause a decline of 0.17% in the technical efficiency levels of the rice farms. On the contrary, an increase of 1% in the number of farm households that join cooperative societies will cause a 0.01% increase in the technical efficiency levels of the farm households. From these evidences we can conclude that access to fertilizer had the highest positive impact on the rice farms technical efficiency levels, while age of the head of the farm households had the highest negative impact of technical efficiency.

Table 79

Elascticities of Covariates of DEA_teVRS

	dy/ex	Delta-method Std. Err.	Z	P>|z|	[95% Conf.	Interval]
Fert_access	0.07	0.021	3.44	0.001	0.032	0.116
Seed_access	0.01	0.015	0.54	0.588	-0.021	0.038
Hebr_access	-0.01	0.005	-1.19	0.232	-0.016	0.004
Mach_access	-0.06	0.013	-4.30	0.000	-0.084	-0.032
Ext_times	0.03	0.022	1.47	0.142	-0.011	0.076
Age	-0.17	0.050	-3.44	0.001	-0.270	-0.074
Coop	0.01	0.008	0.82	0.414	-0.009	0.022
Ownership_storage	-0.04	0.016	-2.67	0.008	-0.073	-0.011

The determinants of the variations in cost efficiency levels of the paddy rice farm households were also examined. Table 80 showed that the key policy determinants of the cost efficiency levels of the rice farm households were access to: fertilizer, seeds, herbicides/insecticides and machinery. However, these determinants were controlled with experience, distance from homes to markets, farm size and ownership of storage facilities. Thus, prior expectations of these variables remain the same as were stated in Table 31. Access to government subsidized fertilizer with a coefficient of 0.457 showed significant relationship with cost efficiency scores for $p < .001$ and had the appropriate positive sign (see Table 80). This implies that as access to government subsidized fertilizer increase, the cost efficiency will also increase as it brings about a reduction in cost of production, *ceteris paribus*.

Access to government subsidized tractor hiring services also had a positive impact of 0.06 according to a prior expectation but was not statistically significant as $p > .05$. Again, this could be traced to the current poor state of tractor hiring services in almost all the sample states. Therefore, increase in access to subsidized tractor hiring services or ownership of tractors will generally, increase cost efficiency through the reduction in cost of labor, which has remained the major constraint to efficiency levels and profitability of paddy rice cultivation business in the country. On the contrary, access to government subsidized and improved seeds had a negative effect but not statistically significant. Perhaps, this could be traced to low acceptance of the new varieties of seeds distributed by government agencies as majority of the farmers still rely on the traditional varieties.

Similarly, access to government subsidized herbicides/insecticides and fungicides showed a negative impact on cost efficiency levels of the paddy rice farms but were statistically significant as $p < .001$. The reason could also be traced to the low emphasis by government policy on the procurement and distribution of herbicides and insecticides. Generally, the government agencies are cautious of the environmental impact and given the low level of education of the rice farmers, they are guiding against the possible misuse.

Table 80

Model 11: Summary of Estimated Impact of Policies on Cost Efficiency

Iteration 0:00	Log	Pseudolikelihood	=	-228.7254
Iteration 1:00	Log	Pseudolikelihood	=	-180.4074
Iteration 2:00	Log	Pseudolikelihood	=	-180.2632
Iteration 3:00	Log	Pseudolikelihood	=	-180.2629
Iteration 4:00	Log	Pseudolikelihood	=	-180.2629
Fractional logistic regression		Number of obs	=	300
		Wald chi2(7)	=	57.46
		Prob > chi2	=	0
Log pseudolikelihood =	-180.278	Pseudo R2	=	0.01

DEA_CE	Coef.	Robust Std. Err.	Z	P>|z|	[95% Conf.	Interval]
Fert_access	0.457	0.109	-5.07	0.000	-0.767	-0.339
Seed_access	-0.151	0.114	-1.29	0.196	-0.373	0.076
Hebr_access	-0.496	0.089	-5.56	0.000	-0.667	-0.319
Mach_access	0.058	0.049	1.3	0.193	-0.032	0.159
Experience	-0.002	0.005	-0.39	0.695	-0.012	0.008
Distance	-0.006	0.011	-0.45	0.653	-0.026	0.016
Farm size	0.015	0.034	0.43	0.664	-0.051	0.081
Ownership_storage	-0.771	0.093	-0.83	0.664	-0.259	0.105
_cons	-1.075	0.130	-8.29	0.000	-1.329	-0.821

An assessment of the effects of specific socioeconomic characteristics of the rice farm households showed that farm size had positive coefficient of 0.02 but was not statistically significant as $p > 0.5$. This means that an increase in farm size based on economies of scale will lead to improvement in cost efficiency. However, ownership of storage facilities further showed a negative effect and was also not statistically significant. The reason as stated earlier in the case of technical efficiency was attributed to the prevalence of traditional silos, which are found to be less cost efficient. Distance to the market had appropriate negative effect but not statistically significant, meaning that reduction in distance, perhaps through improvement in rural road infrastructure could cause an in the cost efficiency levels of the paddy rice farm households and higher profits, *ceteris paribus* (see Table 80).

The Wald Test on the coefficients of the variables was conducted to determine the joint significance of all variables in model 11. Thus, the results of the test are presented below.

```
test
(1)     [DEA_CE] Fert_access = 0
(2)     [DEA_CE] Seed_access = 0
(3)     [DEA_CE] Hebr_access = 0
(4)     [DEA_CE] Mach_access = 0
(5)     [DEA_CE] Experience = 0
(6)     [DEA_CE] Distance = 0
(7)     [DEA_CE] Farm size = 0
(8)     [DEA_CE] Ownership_storage = 0
chi2 (8) =  57.46
Prob > chi2 =  0.0000
```

The χ^2 *p* value was less than 1% of α hence we can reject the null hypothesis assuming that at least some variables in the model were significant. Therefore, we conveniently conclude that the variables in the model have joint effects on the levels of cost efficiency of the rice farm households. Thus, the variables in the model jointly explained to a large extent the variations in cost efficiency scores by rice farm households in the sample.

Table 81 presents the returned results of the elascticities of the covariates in model 11. The results showed that a 1% increase in access to government subsidized fertilizer by rice farmers will improve cost efficiency by 0.09%, meaning that cost of production will reduce and farmers will benefit from enhanced profit. Similarly, a 1% increase in the use of government provided tractors will cause an improvement in cost efficiency levels by 0.01% as this will reduce cost of labor input by rice farms. Meanwhile, the results also showed that a 1% increase in farm size although had a marginal impact, but will improve cost efficiency by 0.003% because of the effect of economies of scale. Access to seeds and herbicides however showed negative elasticities hence these are areas of further research on why their impact were negative.

Table 81

Elascticities of Covariates of DEA_CE

	Delta-method					
	dy/dx	Std. Err.	Z	P>|z|	[95% Conf.	Interval]
Fert_access	0.094	0.023	4.14	0.000	0.050	0.139
Seed_access	-0.031	0.023	-1.33	0.185	-0.077	0.015
Hebr_access	-0.102	0.019	-5.41	0.000	-0.139	-0.065
Mach_access	0.012	0.010	1.19	0.233	-0.008	0.032
Experience	0.000	0.001	-0.42	0.671	-0.002	0.002
Distance	-0.001	0.002	-0.52	0.600	-0.006	0.003
Farm size	0.003	0.007	0.43	0.664	-0.011	0.017
Ownership_storage	-0.016	0.019	-0.83	0.406	-0.053	0.022

Interpretation of Findings

The results so far indicated low profit in rice cultivation business in Nigeria. The low returns are considered not adequate to encourage the youth population to go into the business to replace the ageing rice farmers. The analysis further revealed that moderate technical and low cost efficiencies at 0.721 and 0.295, respectively were the major constraints to improvement in paddy rice output and moderate profit from paddy rice cultivation business. Although there were observed differences of the estimates of technical and cost efficiencies across the three sampled states, but the disparities were not statistically significant, meaning that the respondents in the samples were basically drawn from the same population. Following these observations, we can conclude that inadequate technical efficiency and low cost efficiency levels of the paddy rice farm households were the key constraints to paddy rice production in Nigeria and are the major hindrances to output expansion and reduction in rice importation.

As alluded earlier in this study, government policies geared towards improvement in productive and cost efficiency could be less costly than building new technologies. Hence, such improvements in technical and cost efficiency levels in the rice subsector will not only increase output, reduce importation and save scarce foreign exchange earnings but will also release resources for the remaining subsectors in agriculture sector and other sectors of the economy. Thus, output expansion will enhance national economic growth and impact positively on the general welfare of the citizens.

Evidences from the results of the fieldwork also underscored the importance of the various rice subsector policies initiated so far in boosting productive and cost efficiencies. While some recorded significant impact on technical and cost efficiencies, others showed potentials that they have to raise efficiency and output if further fine tuning can be done by all tiers of government. Therefore, access to subsidized inputs as seen with the Asian Green Revolution could be a major driver of rice output expansion as they impact on the technical and cost efficiency levels of the generality of rice farm households in Nigeria. However, specific evidences gathered showed that there were disparities in the intensity of implementation of current policies across the sample states.

Moreover, the emphasis of government has concentrated on providing access to subsidized fertilizer. Nevertheless, the fertilizer subsidy policy in the past was influenced by the amount of revenue available to government and therefore, was not consistent in terms of prices charged to farmers to purchase fertilizer from government sources. In addition, the prices were rapidly subjected to the volatility in exchange rate coupled with the poor marketing system that has forced some farmers to rely on the local market sources that were exorbitant. The poor attitude of government towards other inputs for rice production remained a major setback at improving the technical and cost efficiencies of the rice farm households, hence leading to low yields, low profit and higher national local rice supply deficit.

Recommendations

In the light of these assessments and the results from observed data of the rice farm households, the study makes the following recommendations for policy formulation and implementation. It should be noted however, that the recommendations are not intended for only the Federal Government but should cut across all other tiers of government including the private sector. These recommendations are enumerated below:

First the governments should strive to bridge the gap between the potential and attainable paddy rice yields. The current average yield of about 2.4 tons per hectare according to the results of the survey is considered too low for a profitable business. Also, the statistically significant disparities in output per hectare across the states also clearly showed the relevance of the differences in intensities of implementation of rice subsector policies and the presence of technologies gaps among the federated states.

Yield is also affected by factors beyond the control of paddy rice farmers such as climate, length of growing season, soil, water, pest pressure, etc. but could also be as a result of socioeconomic factors, crop management practices, access to and use of knowledge and technologies, and lack of deliberate rice subsector policies by the governments. For example, the high rice yield in Australia was attributed to favorable climate: high solar radiation, cloudless long growing season of 150-180 days, optimum temperature, precision crop management in terms of crop rotation, single rice crop per year, smooth and level soil surface, use of registered improved seed with seed replacement every season, precise control of water level, high plant density, need-based, timely, balanced fertilizer application, high quality post-harvest management, enlightened farmers and excellent technical support by governments (Balasubramanian, Bell, & Sombilla, 1999).

Thus, the yield gap compared to the global average yield of 4.5 tons per hectare will therefore require special and continuous interventions on annual basis by all tiers of government. For instance, governments must increase the supply of fertilizer not only for rice cultivation but for the generality of the agriculture sector. As an immediate strategy, the current volatile fertilizer subsidy should be kept at between 40-50% of the market price for a reasonable length of time. In order to save the farmers from exploitation by the fertilizer market participants, the marketing and distribution must be properly organized for farmers to derive maximum benefits from the subsidy policy as it is currently in place.

Other factors that should be addressed by all tiers of government based on the previous analysis of farms and farmers' characteristics, and rice farm management practices should include biological factors (soil, water, seed quality, pests); socioeconomic factors (social/economic status, family size, household income/expenses/investment); farmer knowledge (education level) and experience; farmers' management skills; and farmers' decision making (attitude, objectives, capability, and behavior). These factors must be supported by institutional/policy supports in terms of rural development and infrastructure, land tenure, irrigation and crop insurance. All these factors should be addressed to reduce the yield gaps among farmers.

In particular, the issue of irrigation must be tackle within the medium to long-term to mitigate the impact of harsh weather conditions and the volatile climatic conditions. In the medium term, the government must embark upon the re-vitalization of the moribund irrigation facilities nation-wide. I am aware of the budgetary implications but this can also be achieved through the participation of the private sector with public-private partnership arrangements by federal, state and local governments with token charges on the rice farmers, while the governments subsidizes the facilities with proper tax incentives. The presence of irrigation facilities encourages the farmers to embark on multi-season cropping and allows for about 2 to 3 times harvesting, which can boost output and profit.

Farm technology should be considered as an appropriate step to take as it will enhance efficiency and boost output. Farm mechanization will contribute as it has the potential to reduce the cost of farm labor that constitutes a major hindrance to both technical and cost efficiencies of the paddy rice farm households in Nigeria. Improved farms' mechanization options available to rice farmers are in the areas of land preparation, seed planting and seedling transplanting, and harvesting (minimizes harvest losses).

As discussed previously, no meaningful progress could be achieved without proper farm extension delivery services. The essence of farm extension services is to educate the farmers on modern and improved seeds, other inputs and available rice technologies. This is even more relevant, as majority of the farmers have no formal education above secondary education as shown from the fieldwork. Thus, proper budgetary allocations must be made for the recruitment of trained agricultural extension officers that can specialize on rice production.

In addition, one cannot over-emphasize the importance of credits at affordable interest rate for the rice farmers. The results emerging from the survey showed that about 96% of the farmers interviewed had no access to any formal credit, while the 4% that had access, majority of the proportion received credit from family friends. Thus, since most of the farmers are poor and do not have collateral for formal credit from financial institutions, there is absolute need for government interventions. All tiers of government must therefore, stop paying lip service to the issue of availability of credit to rice farmers in particular, and the generality of farmers in Nigeria.

Second, governments must address the issue of postharvest losses and the quality of locally milled rice. Balasubramanian, Bell, and Sombilla (1999) asserted that about 20% to 25% of the harvested rice is lost before it reaches the consumers' table in most rice producing countries. In the light of this assertion, the postharvest losses in both quantity and quality could also be held responsible to a large extent for substantial profit gaps among paddy rice farmers in Nigeria. For example, a combination of improved processing and modern silos for storage of paddy and milled rice will help farmers to increase their profits as shown by the impact results. Notwithstanding the fact that emerged that majority of the farmers owned storage facilities, the impact on technical and cost efficiency levels of the paddy rice farmers in the samples was not statistically significant. This was as a result of the fact that majority of the storage facilities were traditional types. These impacted negatively on technical and cost efficiency levels of the farmers in general. This is even more relevant as the major objective of rice farmers in Nigeria was largely semi commercial in nature (see Table 33). Despite these results, the observed data showed that none of the farmers owed mill and therefore, were subjected to the profiteering of the contract village millers.

To ensure good profit for the farmers, the government should embark on massive establishment of milling plants through PPP arrangements with tax as well as price incentives. Improvements in the quality of locally milled rice should be a priority so as to ensure fair competition with the imported rice. As urgent, government should encourage the establishment of small scale commercial mills with capacity of 1 to 2 tons per hour and those that use rubber rollers to improve grain quality. Appropriate technologies in postharvest management in terms of provision of modern silos, modern threshing technology, parboiling, etc should be encouraged. Special extension officers should be trained to educate the farmers on these new technologies.

Third a factor militating against moderate profit in paddy rice cultivation business in Nigeria is the exploitative nature of the distribution and marketing system of paddy and locally milled rice. Tinsley (2012) opined that the rice value chain is currently dominated by the exploitative nature of the distributors. The rice value chain consists of numerous and fragmented paddy rice producers and family millers, who do not have enough knowledge of the developments in the local and international rice market. They are equally cash trapped and are ready to sell their products at ridiculously low prices. The distributors who operate between the rural and the urban markets are highly aware of these characteristics and have taken advantage of the situation.

It is argued that the poor resourced farmers have been exploited particularly due to the poor nature of the rural markets with no accessible roads, and other rural market infrastructure. Thus, in terms of benefits from the rice production, the local distributors are the major beneficiaries leaving the farmers in poverty. This bad situation thus calls for the government to reexamine the rural development policy and pay less attention to the politics of rural development and the provision of rural infrastructure.

To complement the agricultural extension officers, government must begin to train and distribute agricultural commercial extension agents, who have the mastery of the market conditions both local and international and should be able to disseminate the knowledge to the farmers. Effective farmer organizations such as cooperatives can assist farmers in production, harvesting and postharvest, processing and marketing, and direct marketing of the product. The government should deplore and effectively use the cooperative officers to educate farmers on the advantages of cooperatives.

To support these recommendations adequate attention should be paid to the impact of age on technical efficiency of the paddy rice farms. The results clearly underscored the fact that, the older the head of the paddy rice farm households, the lower the technical efficiency with its negative impact on total output. Thus, a deliberate policy must be put in place to encourage and attract the younger generation to take to paddy rice cultivation business rather than wonder around in the cities without any meaningful source of livelihood. Adesiji, Omoniwa, Adebayo, Matanmi, and Akangbe, (2009) argued that the major depleting factor on the agriculture sector in Nigeria is the rural-urban drift, which has reduced farm labor in the rural areas. The drift has been a consequence of poor rural infrastructure which has made farming less attractive to the younger generation (Omonigho, 2013)

Above all, these recommendations will not help if there are no proper and effective communication strategies of government intentions to the rice farmers. Successful implementation of new rice technologies will depend largely on the dissemination to farmers in a large area to have a wider impact. The government can deplore effective communication methods such as radio and television (mostly one-way, large audience and time lag); two-way radio and telephone (two-way, timely, need-based and interactive); and distance learning/teaching to spread the knowledge and new rice technologies. They should also equip the various extension agents regularly to pass the knowledge to the farmers. Most importantly, they should use the GIS, crop models, and systems approaches to replicate successful outcomes across states, local councils and wards/districts/villages over time.

In terms of institutional and policy support, formal farmer training institutions, various groups of extension/technology delivery agencies, farm credit organizations, inputs/machinery suppliers, marketing outlets and traders, road, transport and communication networks and product quality and grading centers should be established to encourage farmers to produce rice food efficiently. Policy support in terms of pricing of inputs and outputs, incentives for farmers to encourage rice food production, land tenure, introduction of tax incentives on production of inputs, crop insurance, revitalization of moribund fertilizer companies or their privatization will optimize rice farmers' efficiency and productivity.

Rice is fast becoming a fundamental principal food in Nigeria that is of a major concern to the economy in terms of the amount of foreign exchange allocated to importation of rice. Moreover, it is anticipated that the consumption will rise as the population expands rapidly. As projected, Nigeria will need about U.S$150.0 billion by

2050 to import rice in the light of the rapidly growing demand for rice (Adesina, 2012). Hence, any efforts in arresting the current threat to food security, hunger and disease are good steps in a right direction. Thus, one major area that research should focus in order to avert the negative consequences of expanding dependence on rice importation is to organize a nationwide study in greater detail on assessing the constraints and organize proper analyses state by state and also identifying the needs of the rural people engaged in rice production.

Thus, the nationwide study will serve as an update on issues that were raised in this study and will also provide fresh field data on rice production systems across the federated states and make recommendations on how best to improve current technologies and in addition adapt new rice technologies across the rice producing states in Nigeria that, could bring about rapid technical change in rice production in Nigeria. The study will further illuminate the socioeconomic characteristics of the rural people and identifies how best to engage the people to encourage higher technical and cost efficiencies as well as expand output. The possible addition to this research is to consider continents like Asia, Europe, the Americas and Oceania as model areas and examine rice production in each area and how best to adopt the success stories to Nigeria.

Summary and Conclusion

The report of the study established the fact that rice production and consumption have become relevant globally. Likewise, Nigeria has experienced surge in domestic demand for rice since 1970. In current terms, rice is a strategic staple dietary household item in Nigeria especially, among lower-middle and low income groups. Thus, annual consumption of milled rice in Nigeria has increased more than twenty times since 1960. However, local milled rice production had consistently failed to meet the local demand for rice and associated products. Hence, the gap between local supply and demand is met annually by rice importation. In particular, this has economic implication has it serves as a major drain of the scarce foreign exchange earnings.

In this study, it was therefore established that the deficit has become a major driver for the various government policies initiatives since 2011. In addition, policy initiatives were also motivated by the fact that Nigeria has suitable ecologies for the cultivation of rice to feed the population and also generate surplus for export. Considering the various problems, the Federal Government alongside the sub national governments initiated several subsidy programs of farm inputs, credit programs, land accessibility as well as embarking on policies geared towards the stabilization of appropriate price for paddy rice produced in the country. The intentions of these policies were improvements in technical and cost efficiency levels of paddy rice farmers. Hence, the study was simply to evaluate the impact of these policies on the technical and cost efficiency levels of the rice farm households, using a sample of three states and 300 paddy rice farm households of which 100 of the participants were selected from each state.

The nature of the study was a quantitative and a cross-section research design, which applied a survey technique using structured questionnaire. The data were collected from the respondents through an interview method that lasted eight weeks of which approximately two weeks were spent in each state. The sample size in each state was obtained using the Cochran sample size formula, while equal number of participants in each state was as a result of lack of knowledge of the actual population of paddy rice farm households in each state. The sampling approach was probability sampling applying stratified sampling to select the states and local governments based on their contributions to the national rice output.

Two estimation techniques were used and there were the parametric technique (SF) and the nonparametric technique (DEA). The use of the two distinct techniques was justified by the need to generate comparative estimates that could lead to robust answers for policy formulation and implementation. Data analytical framework used multiple steps in the analysis. First was the consolidation of the data as a whole sample. Second was the consolidation of data on a state-to-state basis. The justification for the use of the multiple steps was perhaps to identify the presence of rice technology disparities and differences in the implementation of the rice subsector policies as a result of differences in resource endowments across the sample states.

Similarly, the data analysis also applied different software for the estimation of results. These were the Excel spreadsheet for organizing the field data and estimation of some summary statistic as well as minor hypothesis testing. Others were the PIM-DEA version 3.2 and the STATA version 14.1 for the estimation of DEA, and OLS/COLS and SF technical and cost efficiency levels of individual paddy rice farm households. The estimations considered the descriptive statistic of the characteristics of paddy rice farm households, the rice farmers characteristics represented by the head of the households, the management practices and production activities. In addition, the analysis also focused on analyzing the profitability of the paddy rice cultivation business as well as the estimation of the technical and cost efficiency of the paddy rice farm households in all the samples as well as at individual state samples.

Finally, the impact of policies on technical and cost efficiencies of the farm households were estimated using the fractional regression model. Tests of hypothesis were considered using the nonparametric technique (Kruskal-Wallis rank tests) and parametric technique (ANOVA). It should be noted that these techniques were used because of the fact that there were three independent samples. The tests were generally used to compare means of variables identified during the analysis so as to underscore the reasons for differences across the state samples. Under the SF models, the log-likelihood ratio tests were applied to determine the presence of technical or cost inefficiency. However, in the analysis of the impact of policies on technical and cost efficiencies, the Wald Test was used to determine the joint significance of the variables in the model explaining the variations in technical and cost efficiency scores by the respondents.

The summary of results of data analysis indicated that rice cultivation was the main occupation of majority of sampled households as well as the major important activity amongst all daily activities. The key objective of paddy rice production in the sampled states was largely semi commercial producing and milling paddy rice for home consumption and sale of any surplus in the local market. Evidence also showed that membership of cooperative societies by paddy rice farm households was low. The paddy rice farmers in the sample states were found to be small holders and also relied substantially on family labor. Furthermore, ownership of important farm assets for rice cultivation was low in all the samples, while only 4.0% of the farmers were able to obtain credits during the cropping season.

In the case of farmers' characteristics, the results showed that majority of the heads of rice farm households were male and none of the producing households owned any processing mills. Thus, those who engaged in milling of rice have relied solely on contract millers. The mean years of experience with paddy rice cultivation was estimated at 9.2 years, while the average distance between homes of the farmers and the local market was moderate compared to the distance between homes and the farms. A large number of the farmers owned storage facilities but were mainly traditional storage facilities.

The data analysis further revealed that irrigation facilities were almost absence in the sampled states as such most of the farmers relied on rain fed cultivation. In this circumstance, almost all the paddy farmers in the samples harvested rice during the 2014/2015 season only once. The observed data analysis confirmed that all respondents engaged paid labor in the farms mainly for preparation of land and harvesting of paddy rice product in almost absence of farm mechanization.

The results further showed that the paddy rice farm households grew both improved rice seeds but more of the traditional rice seeds. The major sources of procuring rice seeds for the period under consideration were government and the local markets. All farmers in the three samples were found to have applied chemical fertilizer for rice production. Two common fertilizer used were the NPK and the Urea and majority of them procured the chemical fertilizer from government sources.

Overall, the analysis of income and cost of production showed that paddy rice production in Nigeria was still profitable but low returns at \$0.44 per kilogram of paddy and milled rice sold. This level of return on paddy rice production efforts was considered inadequate to provide incentives for further expansion or to encourage the youth population to replace the ageing farmers. Similarly, it was considered very poor compared to the returns in other regions/countries like Vietnam were the net margin is about \$0.79. However, the farmers could gain more if their technical, allocative and economic efficiency levels can be improved upon through deliberate policies. As such the results using the DEA and SF approaches produced different results in terms of the technical, allocative and cost efficiency levels of the paddy rice farm households in the samples but indicated some levels of technical and cost inefficiencies.

However, the results indicated that the SF models scored the paddy rice farm household very high in technical efficiency levels at averages of 0.807 and 0.872, respectively for normal half-normal and normal-exponential distribution assumptions of the one-sided error, respectively. Thus, the scores indicated low average technical inefficiency levels, requiring that the farms reduce the overutilization of farm inputs by 0.193 or 19.3% and 0.128 or 12.8% in the same order. Conversely, the DEA technical efficiency models in both the CRS and VRS assumptions of the reference technologies scored the technical efficiency of the paddy rice farms moderately at averages of 0.592 and 0.721, respectively. By implication, the farms will need to reduce input use by 0.408 or 40.8% and 0.279 or 27.9%, in the same order. However, the scores by OLS model for technical efficiency was extremely conservative as technical efficiency of the paddy rice farms was an average of 0.313 or 31.3%, implying that the level of technical inefficiency was too high at an average of about 68.7%.

The results from the estimation of the cost efficiency levels of paddy rice farm households showed the same patterns of variations. The results of the SF using the normal half-normal distribution assumption of the one-sided error term revealed that the average cost efficiency score was 0.863 or 86.3%. Thus, this score means that the average cost inefficiency was estimated at 13.7%, meaning that the farmers needed to reduce cost of inputs through reduction in utilization of inputs or reduction in the proportion of inputs mix. On the contrary, the DEA cost model estimated the average cost efficiency level at 0.295 or 29.5% with an average cost inefficiency of about 70.5%. However, the OLS score was at the middle with an average score of 0.467 or 46.7%. In essence, these levels of technical and cost inefficiency levels were the major concerns of the government that needed to be addressed.

Evidences also underscored the importance of the various rice subsector policies initiated so far in boosting productive and cost efficiencies. While some recorded significant impact on technical and cost efficiencies specifically, access to government subsidized fertilizer was prominent, others showed potentials that they have to raise efficiency levels both technical and cost efficiencies and output. Following the results of the Wald Test, it was established that these variables in both the technical and cost efficiency models jointly accounted for the variations in technical and cost efficiency levels of the rice farm households in Nigeria. In view of this assessment, the study suggested that the implementation of the subsidy policies should be intensified by all tiers of government in Nigeria since these are major drivers of rice output expansion as they impact on the technical and cost efficiency levels of the generality of the paddy rice farm households in Nigeria.

Second, the study concluded that governments must address the issue of postharvest losses and the quality of locally milled rice as they are held responsible to a large extent for the substantial profit gaps among paddy rice farmers. Thus, the following strategies were suggested to include improvement in processing and modern silos for storage of paddy and milled rice; embark on massive establishment of milling plants through PPP arrangements with tax as well as price incentives; ensure an effective distribution and marketing system of paddy and locally milled rice; reexamine the rural development policy and pay less attention to the politics of rural development and the provision of rural infrastructure; train and distribute agricultural commercial extension agents; and ensure that the rice farm households form an effective farmer cooperative organizations.

Above all, the governments should establish proper and effective communication strategies of their intentions to the paddy rice farmers. As such government can deplore effective communication methods such as radio, television, telephone, distance learning/teaching to spread the knowledge and technologies. They should also equip the various extension agents regularly to pass new knowledge to the farmers. Most importantly, they should use the GIS, crop models, and systems approaches to replicate successful outcomes across states, local councils and wards/districts/villages over time.

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Appendix A: Rice Output by States in Nigeria (Thousands of Metric Tons)

States	2000	2005	2010	2011	2012	2013
Abia	17.1	18.5	21.5	22.3	23.4	24.7
Adamawa	143.2	154.9	180.2	186.7	196.4	206.6
Akwa Ibom	0.2	0.2	0.3	0.3	0.3	0.3
Anambra	30.1	32.5	37.9	39.2	41.3	43.4
Bauchi	45.5	49.2	57.2	59.3	62.4	65.6
Bayelsa	97.4	105.4	122.6	127.0	133.6	140.6
Benue	323.0	349.3	406.5	421.1	443.0	466.1
Borno	141.9	153.5	178.6	185.1	194.7	204.8
Cross River	0.2	0.2	0.2	0.2	0.2	0.2
Delta	2.4	2.6	3.0	3.1	3.2	3.4
Ebonyi	130.0	140.6	163.6	169.5	178.3	187.6
Edo	9.2	10.0	11.6	12.1	12.7	13.3
Ekiti	46.1	49.8	58.0	60.0	63.2	66.5
Enugu	33.4	36.1	42.1	43.6	45.8	48.2
Gombe	76.9	83.1	96.8	100.2	105.4	110.9
Imo	0.8	0.9	1.0	1.0	1.1	1.1
Jigawa	21.2	22.9	26.6	27.6	29.0	30.5
Kaduna	665.9	720.2	838.2	868.2	913.5	961.0
Kastina	32.3	34.9	40.7	42.1	44.3	46.6
Kano	133.7	144.6	168.3	174.3	183.4	192.9
Kebbi	76.1	82.3	95.8	99.3	104.4	109.9
Kogi	114.2	123.5	143.7	148.9	156.6	164.8
Kwara	39.6	42.9	49.9	51.7	54.4	57.2
Lagos	4.4	4.7	5.5	5.7	6.0	6.3
Nassarawa	117.7	127.3	148.1	153.4	161.4	169.8
Niger	527.3	570.3	663.7	687.5	723.3	760.9
Ogun	13.8	14.9	17.3	18.0	18.9	19.9
Ondo	50.3	54.4	63.3	65.5	69.0	72.5
Osun	14.5	15.7	18.2	18.9	19.9	20.9
Oyo	1.0	1.1	1.3	1.3	1.4	1.4
Plateau	71.2	77.0	89.6	92.8	97.6	102.7
Rivers	0.0	0.0	0.0	0.0	0.0	0.0

States	2000	2005	2010	2011	2012	2013
Sokoto	15.6	16.9	19.6	20.3	21.4	22.5
Taraba	223.6	241.8	281.4	291.5	306.7	322.7
Yobe	41.2	44.6	51.9	53.7	56.5	59.5
Zamfara	21.4	23.1	26.9	27.9	29.3	30.9
FCT	15.8	17.1	19.9	20.6	21.7	22.8
Total	3298.0	3567.0	4151.0	4300.0	4524.0	4759.2

Note. Data collected from Federal Ministry of Agriculture and Rural Development, Abuja.

Appendix B: Rice Farmer's Questionnaire

A. GENERAL PRODUCER AND HOUSEHOLD CHARACTERISTICS

A1i. Questionnaire Number ……… A2. State ……….. A3. L.G.A. ……………..

A1ii. Town/Village ………………… A5.Agricultural Zone ………………………..

A1iii Farmer name code ……………………………… A7. Interview Date …………….

A2i. Age household head ………… A2ii. Gender household head: 1. Male 2.Female

A2ii. Level of education of household head: 0. None 1. Koranic 2. Adult literacy

3. Primary 4. Secondary 5. Tertiary or any higher education certificate

A2iii. Which of the following activities do you engage in? (Tick as appropriate)

(1) Rice production [ ] (2) Cultivation of arable crops [ ] (3) Poultry keeping [ ]

(4) Livestock rearing [ ] (5) Forestry [ ] (6) Others ……………………

A2iv. Which of these activities is the most important source of your income?

(1) Rice production [ ] (2) Cultivation of arable crops [ ] (3) Poultry keeping [ ]

(4) Livestock rearing [ ] (5) Forestry [ ] (6) Others …………………………

A2v. If rice production, in which year did you commence production? ....

A2vi. Number of years cultivating rice……………………….

A2vii. What is the source of your land for rice cultivation? (1) By inheritance [ ] (2) Rented land [ ] (3) Communal land [ ] (4) Government land [ ]

A2viii. If it is rented land, do you pay rent? (1) No (2) Yes

A2ix. If it is communal or government land are there any charges you pay? (0) No (1) Yes

A3i. Number of persons in your household ……………………………….

A3ii. What is the distance between your house and your farm location? ……….. (Km)

A3iii. What is the distance between your house and the market centre? ……….. (Km)

A3iv. Which of the following means of transport do you have within household? (1) Bicycle [ ]

(2) Motor-cycle [ ] (3) Car/Pick-up van [ ] (4) animal (donkey/cattle/camel) [ ]

A3v. Are you a member of any cooperative society? (0). No (1). Yes

A3vi. What type of Cooperative Society do you belong? (1) Farmers [ ]

(2) Thrift and Loans [ ] (3) Consumer [ ] (4) Any other

A3vii. If yes, which of the following benefits do you enjoy since you became a member?

1. Easy access to bank loan through the cooperative [ ] 2. Economic empowerment [ ]

3. Access to farm inputs from government through the cooperative [ ] 4. Increased output [ ]

5. Economic/social security [ ] 6. Others [ ]

A3viii. What is your major source of obtaining agricultural information?

(1) Radio [ ] (2) Television [ ] (3) Agricultural bulletin [ ](4) Agric extension officers [ ]

(5) Farmer's cooperative society [ ] (6) Others

A3ix.What is the size of your household farm?

(1) Less than or exactly 2 hectares [ ] (2) Between 2 and 5 hectares [ ] (3) Between 5 and 10 hectares [ ] (4) Above 10 hectares [ ]

A4i. What type of field do you cultivate?

S/No.	Type of field	No. of Plots	Total size in Hectares	No. of years of use
1.	Upland			
2.	Lowland			
3.	Mangrove/deep water			
4	Irrigated			

A4ii. If lowland, what type is it? 1. Flood plain (drain into river) [ ] 2. Valley bottom (drains into streams) [ ] 3. Depression (closed area that does not directly drain into stream [ ]

A4iii. For how long have you cultivated in this production system? ....

A4iv. For how long does the field retain water after rains have stopped? ………… months

A4v. If upland, for how long have you cultivated in the system? ....

A4vi. What system do you use in cultivating your rice in any of the production system?

1. Direct seeding [ ] 2. Transplanting from nursery [ ]

A4vii. Is your rice field irrigated? 0. No 1. Yes

A4x. How many times do you harvest your irrigated rice farm in a year?

1. once [ ] 2. twice [ ] 3. thrice [ ]

A5i. What is the water source for your irrigation field?

1. Surface/gravity irrigation [ ] 2. Others …………………………………

A5ii. Do you pay any charges for the water use for irrigation? 0. No 1. Yes

A5iii. If yes, who do you pay the charges to? 1. State ADP [ ] 2. Local Government [ ]

3. River Basin Development Authority [ ] 4. Private irrigation scheme [ ]

A5iv. What are the sources of labor you use in the rice farm?

(1) Family labor [ ] (2) Paid labor [ ] (3) Labor exchange [ ] (4) All of the above

A5v. What is the composition of the labor (No) you engage in the current cropping season?

S/No.	Type of labor	Number	Cost in Naira per	No. of Days Worked

			day	
1.	Family labor			
2.	Paid labor			
3.	Labor Exchange			
	Total			

Notes: Cost include amount paid or imputed for family labor including feeding and transportation

B. DATA ON FARM INPUTS, OUTPUTS AND PRICES

Bi. Please provide the quantities of farm inputs used during this cropping season

Name of Farm Input	Measure	Quantity	Name of Farm Input	Measure	Quantity
1.Farm size	Hectares		11.Interest on loans	Naira	
2. Fertilizer used	Kilograms		12. Others		
3.Rice seeds used	Kilograms				
4.Petrol for pumping water	Liters				
5.Herbicides	Liters				
6.Fungicides	Liters				
7.Insecticides	Liters				
8.Family labor	Numbers x No. of Days				
9.Hired labor	Numbers x No. of Days				
10. Machinery used	No. of Days				

Ibi. Please provide the prices of farm inputs purchased during the cropping season

Name of Farm Input	Measure	Quantity	Unit Price	Name of Farm Input	Measure Unit Price	Quantity
1. Rent on land, if any	Hectares			11.Interest on loans	Naira	
2.Price of Fertilizer used	Kilograms			12. Others		
3.Price of rice seeds used	Kilograms					
4.Price of fuel used	Liters					
5.Price of herbicides used	Liters					

6.Price of fungicides used	Liters					
7.Price of insecticides used	Liters					
8.Imputed family labor wage per day	Numbers x No. of Days					
9.Wage of hired labor per day	Numbers x No. of Days					
10.Cost of machine use per day	No. of Days					
11 Interest amount per day						

Ibi. Please provide the quantities and prices of farm paddy output during the cropping season

Paddy Output	Yield per Hectare	Measure	Quantity	Price
1.				

Big. Please provide information on loan obtained as required in the table below:

	2014/2015
Total Amount (₦)	
Source of credit	
Interest rate (%)	
Interest Amount (₦)	
Duration	

C. FARM MANAGEMENT PRACTICES

C1i. Please provide information on family labor engagement in the table below:

Descriptions	Hours per day worked in the farm	Number of Days worked in a season	Imputed wage per day
Total number of family members			
Male (Number)			

Female (Number)			
Age			
Less than 15 years Male................ Female............			
Between 15 and 45 years Male............ Female.........			
Above 45 years Male.................. Female................			

C1ii. In what farming activities do you utilize your family labor specifically?

Types of Activities	% Utilization	Input cost per day	Number of days Worked	Total cost for the season
Land Preparation				
Planting and Transplanting				
Weed, disease and pest control				
Harvesting				
Post-harvest activities				
Others				

C1iii. In what farming activities do you utilize hired labor and labor exchange specifically?

Types of Activities	% Utilization	Input cost per day	Number of days Worked	Total cost for the season
Land Preparation				
Planting and Transplanting				
Weed, disease and pest control				
Harvesting				
Post-harvest activities				
Others				

C2i. Do you own farm machineries? 0. No 1. Yes

C2ii. If yes, please provide information on the types of farm equipment you have

Types	Numbers	Year of Purchase	Cost of Purchase (N)
Tractors			
Ploughs			
Harvesters			
Pumping machines			
Sprayers			
Water Hose			
Others			

C2iii How do you maintain these equipments? 1. Self, 2. External workmen

C2iv. If external workmen specify the cost of each in this cropping season as in the table below:

Types	Cost of Maintenance (N)
Tractors	
Ploughs	
Harvesters	
Pumping machines	
Sprayers	
Water Hose	
Others	

C2v. If No, do you hire these equipments? 0. No 1. Yes
C2vi. If yes, please provide information on the types of farm equipment you have hired

Types	Numbers	No of Days of Hire	**Cost of Hire per day (N)**
Tractors			
Ploughs			
Harvesters			
Pumping machines			
Sprayers			
Water Hose			
Others			

C3i. How often do you check your rice fields for the purpose of water level control and management?
1. Checking once a week, 2. Checking once in two weeks, 3. Depending on situations

C3ii. Do you drain water level before harvesting? 0. No 1. Yes

C3iii. What are the types of chemical fertilizer used on your rice fields during the cropping season?

Types	Amount used in KG	Price per KG	Total Cost (N)	No. of times applied

C3v. Do you also apply green manure and organic fertilizer on your rice fields during the cropping season?
0. No 1. Yes

C3vi. If yes, please provide the quantity of green manure and organic fertilizer used during the cropping season.............................

C3vii. What are the types of chemical herbicides used on your rice fields during the cropping season for weed control?

Types	Amount used in Liters	Price per liter	Total Cost (N)	No. of times applied

C3viii. What are the types of chemical fungicides used on your rice fields during the cropping season for plant protection?

Types	Amount used in Liters	Price per liter	Total Cost (N)	No. of times applied

C3ix. What are the types of chemical insecticides used on your rice fields during the cropping season for plant protection?

Types	Amount used in Liters	Price per liter	Total Cost (N)	No. of times applied

C3x. Do you use any other traditional means of pest control in your rice farms? 0. No 1. Yes

C3xi. If yes, how much does it cost you, if you incurred any cost..?

C4i. Which rice varieties do you use?

Name of Variety (real or local name)	Traditional or Improved	Type of Production System	Grain type	Growing period	Year of initial use	Original source
1.						
2.						
3.						
4.						
5.						

C4ii. Please provide information on costs

Name of Variety (real or local name)	Quantity Used in KG	Price per KG	Total Cost
1.			
2.			
3.			
4.			
5.			

C4v. How often do you replace rice seed planted?
1 Replace every crop planted 2. Replace every two crop planted 3. Replace every 3 crop planted

C5i. Do you have storage facility for your harvest? 0. No 1. Yes

C6ii. Which of the following storage facility do you possess?

1. local silo [ ] 2. modern silo [ ] 3. Other ……………………………….

C6ii. Did you consume all or part of your rice production? 0. No 1. Yes

C65ii. Give an estimate of the quantity you consumed and the quantity you dispose?

1. Quantity consume (%) ……………… 2. Quantity dispose (%) ……………..

C6iii. Through what means do you dispose your produce of paddy rice?

1. In the farm 2. Through the local paddy market 3. Direct sale to millers 4. Direct sale to government buying agent

C6iv. What method do you use in marketing the rice you produce?

1. Self marketing [ ] 2. Marketing through middlemen [ ] 3. Other ………………..

C6v Do you mill your rice before marketing? 0. No 1. Yes

C6vi. If yes, do you own a rice milling plant? 0. No 1. Yes

C6vii. If no, which source do you use for the milling? 1. Paid milling [ ] 2. Other ……….

C6ix. Which of the following problems do you face in processing/milling your paddy rice?

1. Constant breakdown of plant [ ] 2. High cost of milling [ ] 3. Breakage of the rice fruits during processing [ ] 4. Inadequate number of milling plants [ ] 5. Other ……………………

C6x. Suggest solutions to the problems chosen in E7i.

1) ……………………………………………………………………………….
2) ……………………………………………………………………………….
3) ……………………………………………………………………………….
4) ……………………………………………………………………………….

C6xi. Which of the following problems do you face marketing the locally milled rice?

1. Poor grading and quality control standards for local rice [ ] 2. High incidence of broken grains [ ] 3. High cost of production [ ] 4. Low patronage of local rice [ ] 5. Lack of adequate support for local rice milling/processing [ ] 6. Others …………………………

C6xii. Suggest solutions to the identified problems above.

1) ……………………………………………………………………………………….
2) ………………………………………………………………………………………
3) ………………………………………………………………………………………
4) ………………………………………………………………………………………

D. GOVERNMNT POLICY ACTIONS AND INTERVENTIONS

D1i. Did you receive any form of incentive from the government? 0. No 1. Yes

D1ii. If yes, which of the following did you receive? 1. Fertilizer [ ] 2. Herbicides [ ]
3. Fungicides [ ] 4. Insecticides [ ] 5. Improved seeds/seedlings [ ] 6. Work machines [ ] 7. Finance [ ]
8. Extension services/training [ ] 9. Pest and weed control [ ] 10 others. [ ]

D1iii. Please provide information on the quantity and cost of these farm inputs from governments

Type	Measure	Quantity Received	Price per Unit	Total Cost	Source
1.Fertilizer					
2.Herbicides					
3.Fungicides					
4.Insecticides					
5.Improved Seeds/seedlings					
6. Work Machines					
7. Pest and Weed Control					
8. Credit					

D1iv.Did you get allocation from government land? 0. No 1. Yes
D1v. If yes, what is the size of the land and rent paid?
1. Size......... Hectares 2. Rent paid ₦...............
D1vi. How long have you been farming on government land? .... years

D2i. Did you receive any credit in the last farming season? 0. No 1. Yes

D2ii. What is the main source of your credit? (1) Friends/relations [ ] (2) Community bank [ ]

(3) NACRDB [ ] (4) Deposit Money Banks (DMBs) [ ] (5) ACGSF [ ]

(6) Cooperative society [ ] (7) Micro-credit institutions (e.g. 'Susu ') [ ]

(7) Local money lenders [ ] (8) State government [ ] (9) Local government [ ]

D2iii. If you have not received any credit what is or are the reasons?

0. No need for credit [ ] 1. High cost of borrowing [ ] 3. Difficult to access [ ]

4. Credit not available locally [ ] 5. Others ……………………………………

D2iv. Did your household provide any credit to others? 0. No 1. Yes

D2v. If yes, state amount ₦……………… interest rate (%) ……… duration ……… months.

D3i. Do you have access to government or government appointed extension agents?

D3ii. Estimate the number of extension officer's visits to your farm or house. ....
D3iii. Did the extension officer expose you to new improved seeds and modern techniques of farming?
0. No 1. Yes

D4i If you sell your paddy output through the government buyer, how long does it take you to receive payments? -------

D4ii. Is the payment through 1 Cash 2 Bank?

D4iii. Is there any benefit selling through the government agency?

1...

E. Impressionistic Questions

E1. What are your major rice production problems?

1. ………………………………………………………………………………………..
2. ……………………………………………………………………………………….
3. ……………………………………………………………………………………….
4. ……………………………………………………………………………………….
5. ……………………………………………………………………………………….

E2. What are your suggestions towards solving those problems?

1. …………………………………………………………………………….
2. ……………………………………………………………………………..
3. ……………………
4. ………………………………………………………….
5. …………………………………………………………………………….
6. …………………………………………………………………………….

E3. Suggest ways through which you think the government could further enhance local paddy rice production.

1) …………………………………………………………………………..
2) …………………………………………………………………………..
3) ……………………………………………………………………………
4) ……………………………………………………………………………
5) ……………………………………………………………………………
6) ……………………………………………………………………………

Signature of Questionnaire Administrator: ………………… Date: …………………

Appendix C: States' ADP Rice Information Questionnaire

A. GENERAL

Ai. Questionnaire Number ……… A2. State ………..

Aii. Please provide the basic information on your state for 2014/2015 farming season

Type	2014	2015
1.Agricultural zones Number		
2.State GDP (Naira)		
3. Income per Capita (Naira)		
4.Population		
5.No. of local govt.		
6. Farming population %		
7. Rice farming population (%)		
8.Average Temperature per annum in the state		
8.Average Temperature per annum in the state		
9.State Rice Output (thousand metric tons)		
10. State Land Mass (square kilometers)		

Aiv. Please provide information on the Distribution of the State Rice Output by Local Governments

Local Governments	Rice Output 2014	Rice Output 2015

Av. Which are the major rice production systems in your state?

Production System	Names of Local Governments
1	
2	
3	
4	

Aiii. In the case of Agricultural zones, please provide the list of the zones and the local governments covered by each zone.

Zones	Names of Local Governments
1	
2	
3	
4	
5.	
6	

Aiv. Please provide information on the organization budget

Type	2014	2015
1.Total Budget (Naira, million)		
2.Recurrent Budget (Naira, million)		
3. Capital Budget (Naira, million)		

B. ACTIVITIES

Bi Please provide information on the support by the organization to rice farmers in your state during 2014/2015 farming season

Type	Measure	Total Quantity In 2014/2015 Season	Average Price sold to Framers per Unit of Measure (Naira)
1.Fertilizer			
2.Improved rice seeds			

3. Herbicides			
4. Fungicides			
5.Insecticides			
6.Work Machines Provided			
7.Land			
8.Land clearing			

Bii. Has your organization provided credit to rice farmers in your state? 0 No 1 Yes

Biii. If yes, please complete credit information given below:

Type	2013/2014 Farming Season	2014/2015 Farming Season
1.Total Credit provided (N, million)		
2.Average Credit per farmer (Naira)		
3. Average Number of years of credit		
4.Average Interest Rate %		
5.Average Repayment Rate %		

Biv. What are the sources of credit provided to farmers?

Type of Source	Amount: 2013/2014 Farming Season	Amount: 2014/2015 Farming Season
1.Federal Government (N, million)		
2.State Government (N, million)		
3. Local Government (N, million)		
4.Nigerian Agricultural and Rural Development Bank (N, million)		
5.ACGSF (Naira, million)		
6.Commercial Banks (N, million)		
7.International Agencies (N, million)		
7.Others (N, million)		

Bv. Since your organization maintains a contact list for rice farmers, please provide information on your extension visits to these farmers.

Visits	2013/2014 Farming Season	2014/2015 Farming Season
1.Total number of visits		

2.Average visit per farmer		
3. No. of extension officers employed		

Bvi. Do you engage in weed and pest control of rice farms for the benefit of farmers? 0 No 1 Yes

Bvii. If yes, provide the average control visits to rice farms in your state...................................

Bviii. Please provide any other information that could aid this study

1...

2..

3...

4...

5...

Signature: ………………… Date: …………………

Appendix D: Institutional Review Board (IRB) Number

Approval: 2015.07.2 218:45:11 -05'00'