Thesis

By

SHEHU, JACOB FINTAN

DEPARTMENT OF AGRICULTURAL ECONOMICS FACULTY OF AGRICULTURE UNIVERSITY OF NIGERIA, NSUKKA

PRODUCTION EFFICIENCY DIFFERENTIALS AND INNOVATIVE BEHAVIOUR AMONG RICE FARMERS IN NORTH-EAST, NIGERIA

DECEMBER, 2013

PRODUCTION EFFICIENCY DIFFERENTIALS AND INNOVATIVE BEHAVIOUR AMONG RICE FARMERS IN NORTH-EAST, NIGERIA

BY

SHEHU, JACOB FINTAN

PG/Ph.D/07/43165

DEPARTMENT OF AGRICULTURAL ECONOMICS
FACULTY OF AGRICULTURE
UNIVERSITY OF NIGERIA
NSUKKA

DECEMBER, 2013

PRODUCTION EFFICIENCY DIFFERENTIALS AND INNOVATIVE BEHAVIOUR AMONG RICE FARMERS IN NORTH-EAST, NIGERIA

BY

SHEHU, JACOB FINTAN
PG/Ph.D/07/43165

BEING A Ph.D THESIS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL ECONOMICS, FACULTY OF AGRICULTURE, UNIVERSITY OF NIGERIA, NSUKKA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF DOCTOR OF PHILOSOPHY (Ph.D)
AGRICULTURAL ECONOMICS

DECEMBER, 2013

CERTIFICATION

The thesis titled “**Production Efficiency Differentials and Innovative Behaviour among Rice Farmers in North-East, Nigeria**” meets the regulation governing the award of the Degree of Doctor of Philosophy (Ph.D) Agricultural Economics (Farm Management and Production Economics) of the University of Nigeria, Nsukka and is approved for its contribution to scientific knowledge and literary presentation.

Prof. C. J. Arene **(Supervisor)**	**Prof. E. C. Nwagbo** **(Supervisor)**
Prof. E. C. Okorji **(Head of Department)**	**Prof. D. O. Ogisi** **(External Examiner)**

DEDICATION

To my beloved wife (Framah) and my lovely daughter (Kayla)

ABSTRACT

This study empirically investigated production efficiency differentials and adoption behaviour among rice producers in North-East, Nigeria. The specific objectives were to analyze the socioeconomic and production factors of the rice farmers in the region; measure technical (TE), allocative (AE) and economic (EE) efficiencies of the farmers under traditional and modern production technologies; identify the determinants of TE, AE and EE of the sampled rice farmers; identify factors that influence the adoption of modern production technologies by the rice farmers; and identify constraints associated with rice production in the study area. Data for the study was collected from a sample of 270 rice farmers whose responses were sought on their production activities. Descriptive statistics, Stochastic Frontier Production and Cost Functions, tobit regression and Logistic regression were used in analyzing the data. Results revealed that adopters of modern rice production technologies obtained higher average yield than the non-adopters. The difference between the yields is substantial as attested by the significance of t-value at 1% level. However, there were no significant differences between adopters and non-adopters in terms of age, household size and farming experience. The FRONTIER result showed that the mean TE, AE and EE were 69.1%, 66.1%, 37.6% and 67.6%, 30.3%, 22.4%, respectively for adopters and non-adopters. The tobit result identified family size, education, extension contact, access to credit and system of land ownership as determinants of efficiency. The logistic regression result indicated that farm income, access to information, access to credit, education level of household head, family size and membership of cooperative society played significant role in the influencing farmers' adoption behaviour. Inaccessibility to cheap farm inputs, inadequate rainfall, and conflict with grazing nomads among others were identified as the major problems faced by the sampled farmers. The study concluded that there is substantial difference in the levels of production inefficiencies among the sampled rice farmers; and access to information, literacy level and membership of cooperative society significantly influenced the adoption behaviour of the farmers. The study therefore, recommended that the agricultural extension programme should be revitalized. Additionally, farmers should organize themselves into viable cooperative groups to take advantage of economies of scale in bulk purchase of inputs at subsidized rates.

ACKNOWLEDGEMENTS

I wish to express my profound gratitude to Almighty God for guiding and protecting me throughout my doctoral programme. I would like to express my deepest gratitude to my supervisors, Professor C. J. Arene and late Professor E. C. Nwagbo for their excellent guidance and supervision and unconditional support, which were crucial in completing this thesis. Their support and encouragement are not only in academics but also in my day-to-day life. Because of them, my awful writing in this thesis is still readable. They have set an example as supervisors, teachers, academics, and persons whose character I will aspire to follow.

I would like to thank the Head of Department Professor E. C. Okorji and the entire panel of examiners for their constructive comments. I would like to appreciate the inestimable contribution and encouragement of my mentor Dr. S. I. Mshelia to the success of this thesis. May the good Lord strengthen you to continue to extend this gesture to others.

Special gratitude goes to the Council for the Development of Social Science Research in Africa (CODESRIA) for awarding me grant to facilitate completion of this thesis.

A very big thank you to my dear wife Framah Ladi Agaribas for her love, support, encouragement and patience during the course of my doctoral programme. My mother Mrs. Beatrice Fintan Shehu and my siblings Joel, Francis, Helen and Grovice are worthy of praise for their prayers and encouragement throughout the period of my studies. May God Almighty reward all of you more abundantly.

Special appreciation goes to the family of Dr. and Mrs. Oluwole Matthew Akinnagbe for their hospitality during the period of my studies. May God reward your kind gesture towards me. I would like to appreciate my colleagues in the Department of Agricultural Economics and Extension, Adamawa State University, Mubi for their encouragement and support.

I am greatly indebted to my enumerators and respondents, who, without their tireless efforts in supplying the needed data, this thesis would not have been a success. I pray that God will bless their endeavours.

Finally, I must admit it is impossible to bestow adequate recognition to all who contributed in one way or the other to successful completion of this thesis. Therefore, to those whose names did not appear in this work but have contributed in one way or the other to the success of this thesis, I owe special debts of appreciation.

JACOB FINTAN SHEHU, 2013

TABLE OF CONTENTS

CHAPTER ONE

INTRODUCTION

CHAPTER TWO

LITERATURE REVIEW

CHAPTER THREE

METHODOLOGY

CHAPTER FOUR

RESULTS AND DISCUSSION

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Agriculture has always played a pivotal role in the history of Nigerian economic development by providing food, employment, foreign exchange and poverty reduction. This is because it contributes more than 40% of the total annual Gross Domestic Product (GDP), employs over 70% of the labour force, and accounts for 70% of the earnings from the non-oil sector (Adegboye, 2004; Central Bank of Nigeria, CBN, 2007). Despite the enormous contributions of agriculture to the Nigerian economy over the years, the sector has slipped into a systematic decline in recent years. For instance, the average contribution of the Nigeria's agricultural sector to the Gross Domestic Product (GDP) of 56% between 1960 and 1964 declined to 47% between 1965 and 1969 and down to about 42% in 2006 (Amaza and Olayemi, 2002; Amaza and Maurice, 2005, CBN, 2007). This changing share of the agricultural sector is a clear reflection of decline in agricultural productivity.

In response to the dismal performance of the agricultural sector in the country, successive governments embarked on various programmes and schemes. Some of these include: Farm Settlement Scheme, FSS (1963); National Accelerated Food Production Project, NAFPP (1972); Agricultural Development Programme, ADP (1975); Operation Feed the Nation, OFN (1976); National Seed Service, NSS (1977); Agricultural Credit Guarantee Scheme Fund, ACGSF (1977); River Basin Development Authorities, RBDAs (1977); Green Revolution, GR (1980); Directorate of Food, Roads and Rural Infrastructure, DFRRI (1986); Nigerian Agricultural Insurance company, NAIC (1987); National Agricultural Land Development Authority, NALDA (1991); National Fadama Development Project, NFDP (1992); National Agricultural Research Project, NARP (1998); Nigerian Agricultural Co-operatives and Rural Development Bank, NACRDB (2000); National Agricultural Development Fund, NADF (2002) to mention a few (Nwagbo, 2000; Oredipe and Akinwumi, 2000; Babatunde and Oyatoye, 2004). These agricultural programmes have the common objective of increasing production and productivity in the sector, thereby achieving self-sufficiency in food and fibre. It is however important to state that most of these programmes were terminated without achieving the set objectives.

The Nigeria's food sub sector parades a range of crops, but of all these, rice gained preeminence (Akande, 2001). Nigeria plays a vital role in rice production in West African Sub-region with increasing production over the years. The production of rice in Nigeria rose from 2.5 million metric tonnes (mmt) in 1990 to about 4.0 mmt in 2006 representing about 57% rise in domestic production (Table 1.1). However, despite the rise in domestic production demand/consumption of rice far exceeded local production, precipitating an increase in the rice importation bill to as high a level as US$ 659 million in 2006 (Africa Rice Centre, ARC, 2007). The short fall in supply of rice in Nigeria has been attributed to continued rise in per capita consumption brought about by increased population, rapid urbanization and low yield from farmers' fields. (Akande 2001.; Fabusoro and Agbonlahor, 2002, ARC, 2007).

Heavy reliance on obsolete farming techniques, poor complementary services such as extension, credit, marketing, infrastructure, and inappropriate agricultural policies could also be implicated for the low productivity of the agricultural sector. Table 1 shows the falling yields of ricein Nigeria from 2069.54 kg per hectare in 1990 to 1440 kg per hectare in 2006. This is a worrisome trend. It seems as if Nigeria has not yet been able to take advantage of improvements in agricultural technologies as have other countries in Africa. Achievement of self-sufficiency in rice production must therefore come from improvement on resource productivity through adoption by farmers of yield enhancing technologies.

Nigeria has made substantial investments in agricultural research and extension to increase agricultural production through new technologies. Despite considerable technological change however, agricultural production in this country continued to encounter substantial inefficiencies due to farmers' unfamiliarity with new technology, poor extension and education services, and infrastructure, among others (Ghatak and Ingersent, 1984; Ali and Byerlee, 1991; Xu and Jeffrey, 1998; Shehu, *et al.*, 2007).The slowdown in agricultural productivity growth along with pressuresto reform rural research and development(R&D) policy in Nigeriacould be said to have escalated interestin finding ways to improve productivity, including through enhancing farmers' innovativecapacity. Despite the seemingly simple link, the successful translation of R&D to improved farmproductivity depends on many factors. In particular, much relies on farmers' capacity to adoptsuitable innovations and successfully integrate them into existing farming systems.

Table 1.1: Nigeria's domestic rice output, 1990-2010

Year	Average area cultivated (hectare)	Average output (kg)	Average yield (kg/ha)
1990	1,208,000	2,500,000	2,069.54
1991	1,652,000	3,226,000	1,952.79
1992	1,664,000	3,260,000	1,959.14
1993	1,564,000	3,065,000	1,959.72
1994	1,714,000	2,427,000	1,415.99
1995	1,796,000	2,920,000	1,625.84
1996	1,784,200	3,122,000	1,749.80
1997	2,048,000	3,268,000	1,595.70
1998	2,044,000	3,275,000	1,602.25
1999	2,191,000	3,277,000	1,495.66
2000	2,199,000	3,298,000	1499.77
2001	2,117,000	2,752,000	1299.95
2002	2,185,000	2,928,000	1340.05
2003	2,210,000	3,116,000	1409.96
2004	2,348,000	3,334,000	1419.93
2005	2,494,000	3,567,000	1430.23
2006	2,725,000	3,924,000	1483.30
2007	3,186,000	2,451,000	1299.90
2008	4,179,000	2,382,000	1754.40
2009	3,402,590	1,788,200	1902.80
2010	3,218,760	1,788,200	1800.00

Source: FAOSTAT (2012)

1.2 Problem Statement

In the past two decades, Nigeria's rice sector has witnessed some remarkable developments. However, production increase was insufficient to match the consumption increase; hence, the shortfall has to be met through import. Actual quantities imported have surged from 0.28 million metric tonnes (mmt) in 1990s to 1.6 mmt in 2006 (ARC, 2007). These imports were procured on the world market with accompanying drain on the country's economy. Due to its position as a major staple of most homes in both urban and rural areas, the demand for rice has been increasing at a much faster rate in Nigeria than in other West African countries since 1980s (Table 1.2). For instance, during the 1960s,

Table 1.2: Comparison between Nigeria and the rest of West Africa

INDICATOR	**AVERAGE**					
	1961-1970	**1971-1980**	**1981-1990**	**1991-2000**	**2001-2005**	**2006-2009**
NIGERIA						
Production (tonnes)	264,100	533,200	1,758,132	3,113,800	3,139,400	3,738,313
Import (milled equivalent in tonnes)	1,188	205,908	368,093	283,249	1,226,758	665, 789
Self-reliance ratio (%)	1.33	89.91	87.36	92.63	64.22	78.78
Total Consumption (milled equivalent in tonnes)	138,353	468,413	1,340,588	2,267,615	3,270,270	3, 134, 576
Per capita consumption (Kg/year)	2.76	7.08	15.81	20.27	24.44	21.03
WEST AFRICA WITHOUT NIGERIA						
Production (tonnes)	1,584,129	2,199,480	2,746,537	3,617,028	4,415,048	5,821,130
Import (milled equivalent in tonnes)	357,298	623,186	1,362,258	1,257,658	1,848,198	4, 627, 540
Self-reliance ratio (%)	-0.40	-6.04	-16.21	-16.75	-5.81	58.45
Total Consumption (milled equivalent in tonnes)	1,201,849	1,792,653	2,889,958	3,696,252	5,414,310	10, 845, 386
Per capita consumption (Kg/year)	10.31	9.94	8.53	5.41	-6.11	33.21

Source: Own Computation, ARC, 2007, FAOSTAT 2013, Nigeria had the lowest per capita consumption levels of rice in the sub region (average 10.31 kg/year). Since then, Nigeria's per capita consumption levels have grown significantly. Consequently, per capita consumption during the 1990s averaged 20.27 kg and reached 25.38 kg in 2006.

In a bid to address the countries rice demand-supply gap, the government has interfered in the rice sector over the past few decades. However, public policy in this respect has neither been consistent nor appropriate (Akande, 2001). It has included oscillating import tariffs and import restrictions. For instance, from 1986 to mid-1990s imports were illegal. In 1995, imports were allowed at 100% tariff. In 1996, the tariff was reduced to 50% but later increased to 85% in 2001. Notwithstanding, the various policy measures, domestic rice production has not increased sufficiently to meet the increased demand. Even during the rice import ban period, Nigeria was still importing several hundred thousand tonnes of rice annually through illegal trade.

The limited capacity of the Nigeria's rice sector to meet the domestic demand could be attributed to low resource productivity, inefficiency in the use of productive resources by farmers and disincentives induced by macroeconomic environment. While there are a considerable number of studies dealing with efficiency of farmers in Nigeria (e.g., Chikwendu and Tologbonse, 1992; Arene, 1992; Arene, 1995; Ogar *et al.*, 2002; Ohajianya and Onyeanwaku, 2003, Okoruwa *et al.*, 2006; Moses and Adebayo, 2007; Shehu and Mshelia, 2007), most of these studies have been concerned exclusively with the measurement of technical efficiency. Also,while innovation policy has stronglyfocused on R&D, less attention could be said to have been paid to improving the capacity of firms to adapt andapply innovations. Abroader understanding of innovative capacity and its contribution to farm innovation adoptionand productivity growth can also aid in evaluating policies and investment decisions aimed atimproving productivity growth.

This study, therefore, was designed to measure the level of technical, allocative and economic efficiencies of small-scale rice farmers in Northeastern Nigeria. The relationship between efficiency and farmers socio-economic attributes was also investigated. Furthermore, the study identified some of the factors that influence famers' adoption (innovative) behaviour towards modern rice production technologies in the study area.

1.3 Research Questions

The salient research questions for which answers were sought in this study include:

1. What are the levels of outputs, inputs and socio-economic attributes of adopters and non-adopters of modern rice production technologies?
2. What are the levels of technical, allocative and economic efficiencies of adopters and non-adopters of modern technologies?
3. What are the determinants of efficiencies of the farmers?
4. What are the factors that influence innovative behaviour towards modern rice production technologies?
5. What are the problems faced by the farmers?

1.4 Objectives of the study

The broad objective of this study was to examine the production efficiency differentials and innovative (adoption) behaviour among rice farmers in North-Eastern Nigeria. The specific objectives were to:

i. compare the output and inputs levels and socioeconomic attributes of adopters and non-adopters of modern rice production technologies;

ii. measure technical, allocative and economic efficiencies of adopters and non-adopters of modern rice production technologies;

iii. identify the determinants of technical, allocative and economic efficiencies of the rice farmers in the region;

iv. identify factors that influence the farmers innovative (adoption) behaviour towards modern rice production technologies in the region; and

v. identify constraints associated with rice production in the study area.

1 .5 Research Hypothesis

To guide this study in arriving at meaningful results, the following null hypotheses were tested:

i. Rice producers in the study area are not fully technically and cost efficient.
ii. There is no difference in mean efficiency of adopters and non-adopters of modern rice technologies.
iii. Socioeconomic and institutional factors have no influence on farmers' innovative behaviour.

1.6 Justification of the study

Although agriculture in developing countries has undergone considerable technological changes, there have been evidences of substantial inefficiency in agricultural production due to farmers' high unfamiliarity with new technology, poor education and extension services, and poor infrastructure, among others (Ali and Chaudhry, 1990). An investigation of farm level productive inefficiencies and the underlying causes associated with the use of improved agricultural technologies would greatly help policy makers to take the necessary corrective measures for enhancing agricultural production through better and efficient use of these technologies alongside the limited farm resources.

Knowledge about the extent of production inefficiencies under modern technology and the associated responsible factors will enormously help policy makers to explore untapped potentials of new technology and increase food production with existing resources by addressing the identified constraints. It will also enable the identification of those farmers who need the most support from the government and hence help for better targeting and priority setting. Additionally, knowledge about the production efficiency gaps between users and non-users of modern technology will inform policy makers of the impact of modern agricultural technologies.

While various incentive measures have been used to induce farmers to achieve high rate of adoption of modern technologies (use of fertilizers, improved seeds, herbicide application, pesticides application, etc.), little effort has been made to examine factors that influence the adoption or otherwise of these technologies. Our understanding of the factors that affect the adoption of modern agricultural technology, which this study intend to explore, will provide information that policy makers need to redress the policy failures associated with technology promotion in Nigeria.

1.7 Limitations of the Study

Although it would have been useful to include all the states to attain a broader understanding of the production efficiency and innovative behaviour of the rice farmers in North-East, Nigeria, in this study it was not possible due to inadequate time and resources. Consequently, only 10 Local Government Areas (LGAs) from three states were sampled. Another limitation was the scarcity of recent literature relating to the production efficiency measurement in Nigerian context. Most of the recent literature that was accessible was from western countries, which was not always relevant to the local situation in Nigeria.

The study was also limited to a representative sample due to the high expenses involved in terms of time and funds if a longitudinal study had to be conducted. Furthermore, the representative sample used was limited in scope to enable the generalization of the findings from the study on the differences in production efficiency of adopters and non-adopters of modern rice production technologies. The findings of this study may consequently not be generalized to all the geo-political regions in the country, since different geographical areas may have their own peculiar characteristics in terms of location, the socio-economic status of farmers and production techniques.

CHAPTER TWO

LITERATURE REVIEW

In this chapter, a review of literature on efficiency and adoption is provided. Some concepts in production efficiency were discussed. Theoretical framework on efficiency measurement and farmers adoption behaviour is presented in section 2.2. In Section 2.3, analytical models on efficiency and adoption analyses were discussed. Finally, reviews of empirical studies related to the research were also presented.

2.1 Conceptual Framework

2.1.1 Production possibility set

Let a production technology utilize a vector of inputs, denoted by $x = (x_1,..,x_n) \in \Re^n$ to produce a non-negative vector of outputs, denoted by $y = (y_1,.......,y_m) \in \Re^m$. The production possibility set of a production unit (PU) is a subset T of the space $\Re^{m+n}$. A PU unit may select an input-output configuration $(x, y) \in T$ as its production plan. The production possibility set is the collection of all feasible input and output vectors. It is represented as

$$T = \{(y, x): x \text{ can produce } y\} \subset \Re^{m+n} \qquad (2.1)$$

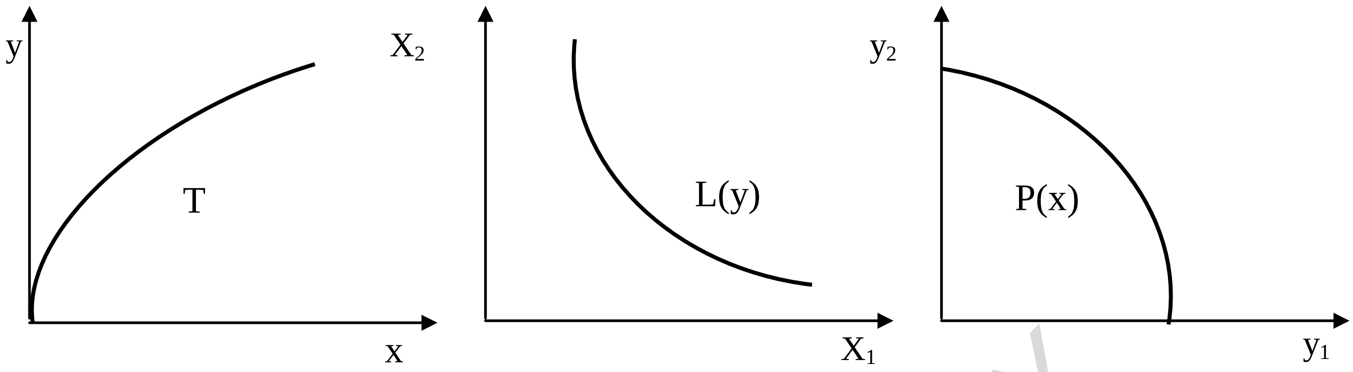
Furthermore, production possibility set can be represented by input requirement set L(y) or output producible set P(x) (Färe, Grosskopf and Lovell, 1994). The input requirement set represents the collection of all input vectors $x = (x_1,..,x_n) \in \Re^n$ that yield at least output vector $y = (y_1,.......,y_m) \in \Re^m$. It can be represented as:

$$L(y) = \{x: (x, y) \text{ is feasible}\} \qquad (2.2)$$

The output producible set is the collection of all output vectors $y = (y_1,.......,y_m) \in \Re^m$ that are produced from the given input vector $x = (x_1,..,x_n) \in \Re^n$. It can be represented as:

$$P(x) = \{y: (y, x) \text{ is feasible}\} \qquad (2.3)$$

These production possibility sets are illustrated in Figure 2.1 below:



a) Technology Set b) Input requirement set c) Output producible set

Figure 2.1: Production Possibility Sets

2.1.2 Production frontiers

To illustrate the concept of production frontier, one can use an important class of technologies having a single output y and an n- dimensional vector of input x. Suppose the production possibility set satisfies $T(x, y) \geq 0$, a general representation of the frontier technology is given as:

$$y = f(x) \qquad (2.4)$$

The function f (.) is the production frontier and equation (*2.4*) gives the upper boundary of T. Given input x, the maximum producible output $y = f(x)$ can be achieved. In the form of maximization, the production frontier is expressed by:

$$f(x) = \max \{y' : T(x, y') \geq 0\} \qquad (2.5)$$

The production frontier serves as a standard against which to measure the technical efficiency of production. It should contain only the efficient observations (PUs). Production frontier has a property scale economies: constant returns to scale, decreasing returns to scale and increasing returns to scale (Coelli *et al.*, 1998).

2.1.3 Efficiency

The concept of efficiency is concerned with the relative performance of the processes used in transforming given inputs into outputs. The crucial role of efficiency in increasing agricultural output has been widely recognized by researchers and policy makers (Bravo-Ureta and Evenson, 1994; Bravo-Ureta and Pinheiro, 1997; Obwona, 2000; Ogar *et al.*, 2002; Ogundele, 2006; Okoruwa *et al.*, 2006; Mbanasor and Kalu, 2008). An important assumption relating to efficiency measurement is that firms operate on the outer bound production function, that is, on the efficiency frontier. Efficiency measurement is very important for monitoring productivity growth. It ascertains the extent to which it is possible to increase productivity using underlying resource base and available technologies.

Efficiency is measured by comparing the actually attained or realized value of the objective function against what is attainable at the frontier. The resource constraint makes increasing efficiency one of the important goals of any individual and society since efficiency improvement is one of the important sources growth. Thus, efficiency has policy implications both at the micro and macroeconomic levels.

The farm household unit is both a family and an enterprise that simultaneously engages itself in both consumption and production activities. This dual economic character of the farm household has implications for the economic analysis that can be made on it. The hypothesis that farm households are efficient is attributed to the farm household motivation of profit maximization. Efficiency and profit maximization are two sides of the same coin in that at a level of individual production unit you cannot have one without the other. The strict definition of economic efficiency requires a competitive market, since neither the individual production unit nor the sector can attain efficiency if different producers face different prices or if some economic agents can influence the prices and returns of other economic agents (Ellis, 1993).

2.1.4 Components of production efficiency

In microeconomic theory of the firm, production efficiency is decomposed into technical and allocative efficiency. A producer is said to be technically efficient if production occurs on the boundary of the producer's production possibilities set, and technically inefficient if production occurs on the interior of the production possibilities set. That is, technical efficiency is the extent to which the maximum possible output is achieved from a given combination of inputs (Ellis, 1988). On the other hand, a producer is said to be allocatively efficient if production occurs in a region of the production possibilities set that satisfies the producer's behavioural objective.

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

2.1.5 Efficiency hypothesis

In the economic literature on efficiency, an important and often controversial subject is what is called the efficiency hypothesis. The notion that traditional farmers are "poor but efficient" in their static environment has often been a view that drew the attention of several economists. The efficiency hypothesis, which was advanced by Schultz (1964) states that farm families in the developing countries are "poor but efficient". He explicitly stated that there is comparatively little significant inefficiency in the allocation of the factors of production in traditional agriculture.

According to the hypothesis, since peasants are efficient within the constraints of existing technology; then only a change in the technology will bring about an increase in output. This hypothesis had influenced the perception of economist for a long time and its policy implications had remained to be of central importance in resource allocation (Alene, 2003). Accordingly, new investments and technological inputs from outside have been increasingly emphasized rather than extension and education effort.

Conceptually, the "poor but efficient" hypothesis is related to a situation where external conditions are steady and not to situations which leave the farmer in a continuous disequilibrium. But farmers' environment is in continuous motion, which necessitates an alteration in technological, economic and ecological conditions. The growing degradation of tropical soils as well as the high man-land ratios under population pressure are best indicators for the disturbances of traditional farming systems. Different measures adopted by farmers to adjust to the rapidly changing environment create possibilities for substantial differences in efficiency. Ali and Chaudhry (1990) observed that farmers also find themselves in disequilibrium because of the continuously generated and diffused new technological innovation as well as by the continuous changes in input and output prices.

In addition to the conceptual argument, the ”poor but efficient” hypothesis has also been a subject for a number of empirical investigations. For example, Shapiro (1983) rejected this hypothesis after reviewing previous studies. He performed his empirical investigation of cotton farmers in Tanzania and found that output could be increased by 51 percent. This, he reasoned, could be brought about if all farmers achieved those levels of technical efficiency that were in fact achieved by the best farmers in the sample using the inputs and technologies that the less efficient ones used. Also, 25 to 50 percent inefficiencies in rice production were reported from studies conducted in the Philippines (Lingard *et al.*, 1983; Dawson and Lingard, 1989). It was also reported that the profit of Paskitanis rice farmers could be increased by 28 percent by improving their efficiency (Ali and Flinn, 1989). Ali and Chaudhry (1990) reported that income of farmers in Punjab could be raised by 13 to 30 percent using the prevailing technology during the study period. A study in southwestern Nigeria indicated that output of farmers could be raised by 30 to 46 percent by improving their efficiency (Ajibefun and Aderinola, 2003). In a more recent study conducted in Nigeria, Ogundari and Ojo (2006) reported that output of smallholder cassava farmers in Osun State could be increased by 11 percent by improving their efficiency.

So, from the foregoing, it could be said that the universal validity of this hypothesis is questionable in an environment that is no longer static and is characterized by substantial changes of technology, economy and environment. Also, it is virtually impossible to meet the assumptions of facing the same production technology; and input and output prices and accept the profit-maximizing behaviour of peasants. Rejecting the “poor but efficient” hypothesis does not however necessarily imply that the theory does not have any contribution. It has, at least been successful in placing peasant economics rationally on the agenda.

The Schultzian hypothesis was the point of departure for taking much more seriously the logic of peasant farming systems in order to discover the underlying logic of peasant farm practices instead of dismissing them as backward, lazy and irrational. This theory of profit maximization, which was the basis for the "poor but efficient" hypothesis, is only one of the theories advanced to explain peasant household behaviour. Several other alternative economic theories of peasant households have been presented in the literature. These include the Chayanov model of utility maximization (Chayanov, 1966) which sets up a theory of the peasant household which contains both consumption and production components and is based upon two basic assumptions: the absence of labour market and the flexible access to land. The new household model (Singh *et al.*, 1986) which is similar to the Chayanovian model, relax some of the assumptions while at the same time maintain the integration between consumption and production. The risk-averse peasant model (Ellis, 1988) which argues that poor small farmers are necessarily risk-averse and they attempt to increase family security rather than maximize profit.

Ellis (1988) pointed out that none of these theories assume or predict that peasant farmers are uniformly technically efficient in the sense that they all operate on the same 'best' production function. The simple conclusion to draw from this is that varying technical efficiency amongst peasant farms is always worth investigating irrespective of the microeconomic theory of the farm household.

2.1.6 Efficiency under new technology

Since modern agricultural technology is recognized to be an important tool for increasing agricultural production, policy makers have paid attention mainly to the choice of technology and to the adoption of such chosen technology by farmers (Kalirajan, 1991; Ali and Chaudhry, 1990). Following the neoclassical Hirschman's model of economic development, policy makers in developing countries have followed the method of providing various incentive measures to induce farmers to achieve a high rate of adoption of chosen modern technology. Contrary to the expectation, the field-level performances of many new technologies have been shown to be as suggested by the Hirschman's model of development. In this context, Schumpeterian theory of development provides an explanation. It stresses the fact that technological progress depends not only on the choice of technology but also on the appropriate application of any technology (Kalirajan, 1991).

With the introduction of a new input (e.g. a new variety), farmers may experience initial inefficiency as they learn about the new input. This inefficiency may include technical inefficiency as farmers acquire skills in applying the input and allocative errors as they adjust the level of use of the new input to their own specific circumstances (Ghatak and Ingersent, 1984; Ali and Byerlee, 1991; Xu and Jeffrey, 1998). This is especially true if the environmental variables have strong interaction with the new inputs. If the introduction of a new input is a one-time change to the system, farmers will eventually adjust to a reasonably efficient use of the input through learning by doing. In practice, agriculture in developing countries has undergone profound changes in both technical and economic environments. Changes in technical environment are often accompanied by changes in the economic environment. The development of better transportation and marketing infrastructure encourages specialization. At the same time, 1nput-output price relationships are subject to sharp changes, especially with the policy reforms in many developing countries, which have gradually eliminated subsidies on critical inputs such as fertilizers. The combination of an evolving technical and economic environment means that the equilibrium required for economic efficiency is a constantly moving target (Ali and Byerlee, 1991).

2.2 Theoretical framework

2.2.1 Efficiency measurement

The measurement of efficiency begins with Farrell (1957) who drew upon the work of Debreu (1951) and Koopmans (1951) to define a simple measure of firm efficiency which could account for multiple inputs. He proposed that the efficiency of a firm consists of two components: technical efficiency (TE), which reflects the ability of a firm to obtain maximal output from a given set of inputs, and allocative efficiency (AE), which reflects the ability of a firm to use the inputs in optimal proportions, given their respective price. These two measures are then combined to provide a measure of total economic efficiency.

Farrell illustrated his ideas using a simple example involving firms which use two inputs to produce a single output under an assumption of constant returns to scale. In Figure 1 below, observation A uses two inputs to produce a single output. SS$^/$ is the efficient isoquant estimated with an available technique. Now, point B on the isoquant represents the efficient reference of observation of A. The TE of production unit operating at A is measured by the ratio TE = OB/OA which is equal to one minus BA/OB. It will take a value between zero and one, and hence an indicator of the degree of technical inefficiency of the production unit. A value of one indicates that the firm is fully technically efficient. For instance the point B is technically efficient because it lies on the efficient isoquant.

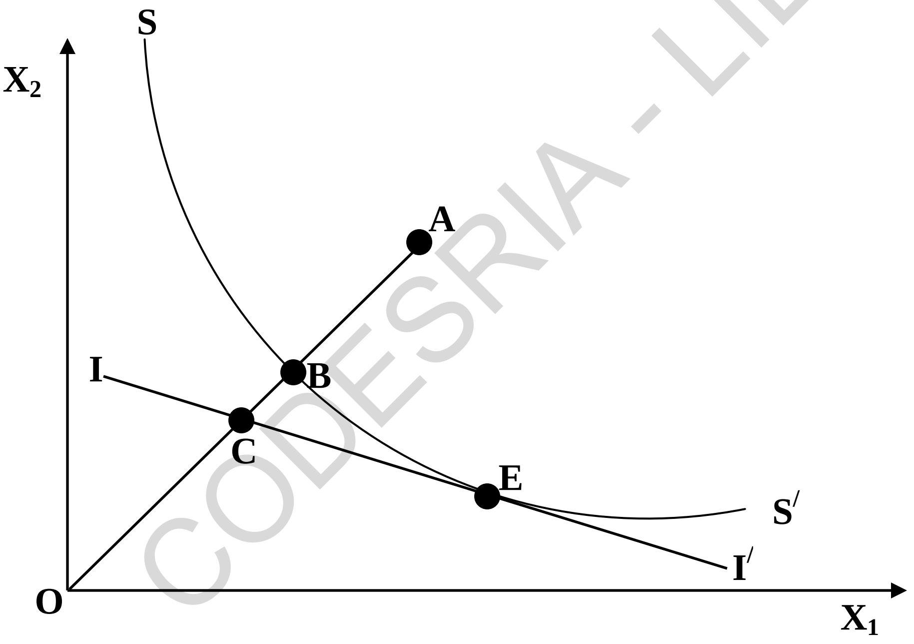


Figure 2.2: Technical and Allocative Efficiencies

If the input price ratio, represented by the slope of the isocost line, **II**$^/$ in Figure 2.2, is also known, allocative efficiency may also be calculated. The allocative efficiency (AE) of a production unit operating at point A is defined to be the ratio AE = OC/OB since the distance CB represents reduction in production costs that might occur if production were to occur at allocatively (and technically) efficient point E, instead of at the technically efficient, but allocatively inefficient point B.

The total economic efficiency (EE) is defined by the ratio EE = OC/OA where the distance CA can also be interpreted in terms of cost reduction. Note that, the product of technical efficiency and allocative efficiency measures provide the measure of total economic efficiency.

TE x AE = (OB/OA) x (OC/OB) = OC/OA = EE

Note that all three measures are bounded by zero and one.

These efficiency measures assume the production function of the fully efficient firm is known. In practice this is not the case, and the efficient isoquant must be estimated from the sample data. Farrell suggested the use of either (a) a non-parametric piecewise-linear convex isoquant constructed such that no observed point should lie to the left or below it (Figure 2.3), or (b) a parametric function such as the Cobb-Douglas form, fitted to the data, again such that no observed point should lie to the left or below it.

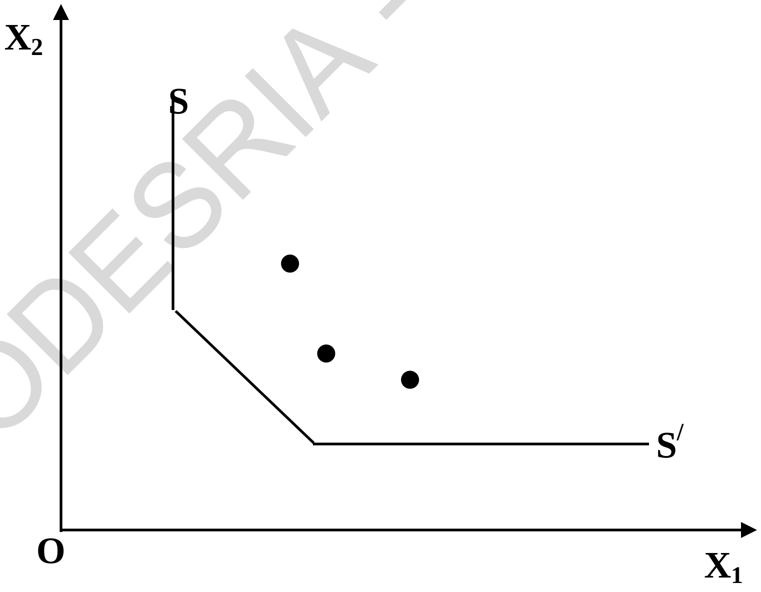
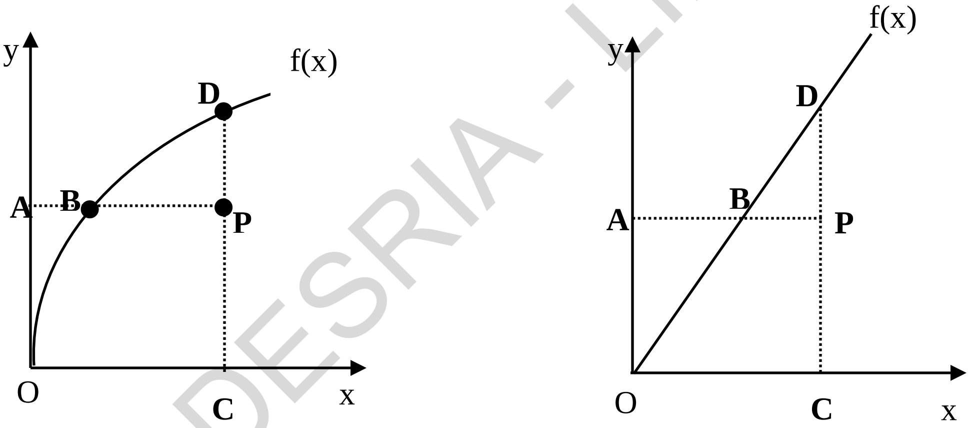


Figure 2.3: Piecewise Linear Convex Isoquant

The above input-oriented technical efficiency measure addresses the question, “By how much can input quantities be proportionally reduced without changing the output quantities produced?” One could alternatively ask the question, “By how much can output quantities be proportionally expanded without altering the input quantities used?” This is an output-oriented measure (Figure 2.4) as opposed to the input-oriented measure discussed earlier. The difference between the output-and input-oriented measures can be illustrated using a simple example involving one input and one output. This is depicted in Figure 4 (a) where we have decreasing returns to scale technology represented by f (x), and an inefficient firm operating at the point P. The Farrell input-oriented measure of TE would be equal to the ratio AB/AP, while the output-oriented measure of TE would be CP/CD. The output- and input-oriented measures provide equivalent measures of technical efficiency when constant returns to scale exist, but are unequal when increasing or decreasing returns to scale are present (Färe and Lovell, 1978). The constant returns to scale case is depicted in Figure 2.4 (b) where it is observed that AB/AP=CP/CD, for any inefficient point P chosen.



(a) Diminishing Returns to Scale

(b) Constant Returns to Scale

Figure 2.4: Output and input oriented measure of technical efficiency

One can consider output-oriented measures further by considering the case where the production involves two outputs (y_1 and y_2) and single input (x_1). Again, if we assume constant returns to scale, we represent the technology as a production possibility curve in two dimensions. This example is depicted in Figure 2.5 where the line $ZZ^{/}$ is the unit of production possibility curve and the point A corresponds to an inefficient firm.

Note that the inefficient point A, lies below the curve in this case because $ZZ^{/}$ represent the upper bound of production possibilities.

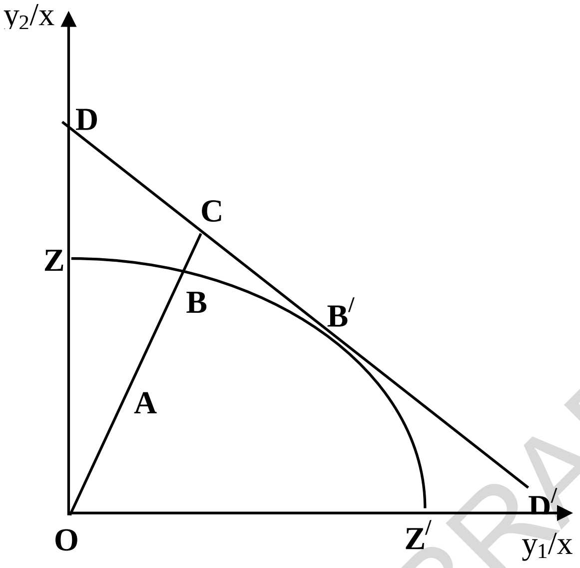


Figure 2.5: Output oriented Technical and Allocative Efficiencies

The Farrell output-oriented efficiency measures would be defined as follows. In Figure 4 the distance AB represents technical inefficiency. That is, the amount by which outputs can be increased without requiring extra input. Hence, a measure of output-oriented technical efficiency (TEo) is the ratio OA to OB. If we have price information, then we can draw the isorevenue line DD$^{/}$ and define the output oriented allocative efficiency (AEo) to be OB/OC which has a revenue increasing interpretation (similar to the cost reducing interpretation of allocative inefficiency in the input-oriented case). Furthermore, one can define total economic efficiency as the product of these two measures, EEo=OA/OC= (OA/OB) x (OB/OC) = TEo x AEo. Again, all these measures are bounded by zero and one.

2.2.2 Approaches toefficiency measurement

The measurement of production efficiency has been highly recognized as an important exercise in view of its relative for policy makers in showing whether it is possible to increase output by simply increasing the efficiency of the firm without substantial additional resources. The methodologies for examining the production efficiency of farmers can generally be grouped into four different broad categories: the average factor productivity estimates; the linear programming approach; the production function approach; and the profit-function methodology.

A simple comparison of total factor productivity is not a satisfactory efficiency indicator because farm households differ with respect to factor proportions, subsistence needs, and off-farm income opportunities, all of which have an impact on the revenue obtainable from a given resource endowment (de Haen and Runge-Metzger, 1989). The attempts to overcome this shortcoming led to the development of total factor productivity indexes in which a weighted average of inputs was compared with average output. The profit function approach is also seriously criticized because of its assumption of profit maximization as the given objective in the allocation process (Ellis, 1988). Farmers' objectives may not necessarily be that of profit maximization. Utility maximization or minimizing risk could be important factors influencing farmers' decision making.

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

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

Given the definition of a production function, interest has then centered more on specifying and locating the production frontier. Alternative production models have often been proposed and the frontier is one of these models and there seems to be a consensus in the recent literature on production function estimation that the production frontier rather than the average production function corresponds to the theoretical notions of the production function. Farrell (1957) had been the pioneer who introduced the frontier measure of efficiency, which reflects actual firm performances, and include all relevant factors of production.

The frontier production function approach has some obvious advantages over the traditional methodologies and its use has therefore become widespread. The primary advantage of the method is that it is more closely related to the theoretical definition of a production function, which relates to the maximum output attainable from given set of inputs. The second advantage of the method lies in the fact that the estimates of technical efficiency of a firm in the sample may be obtained by comparing the observed output with the predicted (or attainable) output. Deviations from the frontier have acceptable interpretations as measures of the inefficiency of economic units. This approach provides a benchmark against which one can measure the relative efficiency of a firm. The production frontier is, however, unknown and it had to be empirically constructed from observed data in order to compare the position of a firm or a farm relative to the frontier. Several methods have been developed for the empirical measurement of frontier models. The different methods that are developed to estimate the frontier production function can be categorized based on certain major criteria (Assefa, 1995). First, based on the way the frontier is specified, the frontier may be specified as a parametric function or as a non-parametric function. Second, based on the way the frontier is estimated, the frontier may be estimated either through programming techniques or through the explicit use of statistical procedures. Third, based on the way the deviations from the frontier are interpreted, deviations may be interpreted simply as inefficiencies or they could be treated as mixtures of inefficiency and statistical noise.

Farrell (1957) original work formed the basis of the non-parametric programming method with subsequent extensions of his work by Charnes *et al.* (1978) and Färe *et al.* (1985) giving rise to what is often referred to as Data Envelopment Analysis (DEA). In this approach, technical efficiency is defined as the minimum input for any particular combination of outputs. Farrel's original approach of computing the efficiency frontier as a convex hull in the input coefficient space was generalized to multiple outputs. This was reformulated into calculating the individual input saving efficiency measures by solving a linear programming (LP) problem for each unit by Charnes *et al.* (1978) under the constant returns to scale assumption. Färe *et al.* (1994), Banker *et al.* (1984) and Byrnes *et al.* (1984) extended this approach to the case of variable returns to scale and developed corresponding efficiency measures. DEA method involves the use of linear programming to construct a piecewise linear envelopment frontier over the data points such that points lie on or below the production frontier. Let X be a K x N matrix of inputs, which is constructed by placing the input vectors, x_i, of all N firms side by side, and Y denotes the M x N output matrix which is formed in an analogous manner.

The output-oriented variable returns to scale of DEA frontier is defined by the solution to N linear programs of the form

$$\begin{aligned} &\max_{\phi,\lambda}\phi, && (2.6)\\ &\text{subject to} \quad -\phi y_i + Y\lambda \geq 0,\\ &\qquad\qquad\quad x_i - X\lambda \geq 0,\\ &\qquad\qquad\quad N1'\lambda = 1\\ &\qquad\qquad\quad \lambda = 0, \end{aligned}$$

where N1 is an N x 1 vector of ones, λ is an N x 1 vector of weights and ϕ is the output distance measure. $1 \leq \phi \leq \infty$, and $\phi - 1$ is the proportional increase in outputs that could be achieved by the ith firm, with input quantities held constant. Note that $1/\phi$ defines a technical efficiency score which varies between zero and one.

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

$$\begin{aligned} &\min_{\rho,\lambda}\rho, && (2.7)\\ &\text{subject to} \quad -y_i + Y\lambda \geq 0,\\ &\qquad\qquad\quad x_i/\rho - X\lambda \geq 0,\\ &\qquad\qquad\quad N1'\lambda = 1\\ &\qquad\qquad\quad \lambda = 0, \end{aligned}$$

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

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

$$\begin{aligned} &\min_{\theta_t^{CRS}} \theta_t^{CRS} && && (2.8) \\ &\text{subject to} && -Y\lambda + y_i \leq 0, && \\ & && \theta_t^{CRS} x_i - X\lambda \geq 0, && \\ & && \lambda = 0, && \end{aligned}$$

where θ_t^{CRS} is a technical efficiency measure of the ith firm under constant returns to scale and $0 \leq \theta_t^{CRS} \leq 1$. The output and input oriented models will estimate exactly the same frontier surface and, therefore, by definition, identify the same set of firms as being efficient. The efficiency measures may, however, differ between the input and output orientations. Under the assumption of constant returns to scale, the estimated frontier and the efficiency measures remain unaffected by the choice of orientation (Coelli and Perelman, 1999).

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

Although Farrell's non-parametric approach has won few adherents, a second approach proposed by Farrel has proved more fruitful. Almost as an afterthought, Farrel (1957) proposed computing a parametric convex hull of the observed input-output ratios. For this purpose, he recommended the Cobb-Douglas production function. Although Farrell acknowledged the undesirability of imposing a specific and restricted functional form on the frontier, he noted the advantage of being able to express the frontier in a mathematical form.

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

$$\ln Y_i = \ln f(X_i;\beta) - u_i, \qquad (2.9)$$

where Yi is the output of the ith firm, Xi is the input of the ith firm and u_i is a one-sided disturbance term. The one-sided error term forces $Y \leq f(X)$. The elements of the parameter vector β may be estimated either by linear programming (i.e., minimizing the sum of the absolute values of the residuals, subject to the constraint that each residual be non-positive) or by quadratic programming (i.e., minimizing the sum of squared residuals, subject to the same constraint). The authors suggested that minimization of the sum of absolute deviations $\Sigma|Y_i - f(X_i;\beta)|$, subject to $Y \leq f(X_i, \beta)$, which is a linear programming problem if $f(X_i;\beta)$ is linear in β. This is equivalent to minimization of the one-sided error term, u_i. Alternatively, the suggested minimization of the sum of squared deviations $\Sigma|Y_i - f(X_i;\beta)|^2$, subject to the same constraint, which is a quadratic programming problem if $f(X_i;\beta)$ is linear in β. Although Aigner and Chu (1968) did not do so, the technical efficiency of each observation can be computed directly from the vector of residuals, since u_i represents technical inefficiency.

The principal advantage of the parametric deterministic approach vis-à-vis the non-parametric approach is the ability to characterize frontier technology in a simple mathematical form. However, the mathematical form may be too simple. The parametric approach imposes a structure on the frontier that may be unwarranted. The restrictive homogeneous Cobb-Douglas specification has been relaxed by Forsund and Jansen (1977) and Forsund and Hajlmarsson (1979), among others. The parametric approach often imposes limitations on the number of observations that can be technically efficient. In the homogeneous Cobb-Douglas case, for example, when the linear programming algorithm is used, there will, in general, be only as many technically efficient observations as there are parameters to be estimated. As was the case with the non-parametric frontier, the estimated frontier is supported by a subset of the data and is therefore extremely sensitive to outliers. One possibility suggested by Aigner and Chu (1968) and implemented by Timmer (1971) was essential just to discard a few observations. This has led to the development of the so-called probabilistic frontiers, which are estimated by the type of mathematical programming techniques discussed above; except that some specified proportion of the observations is allowed exceed the frontier. Although this feature was considered desirable because of the likely incidence of outlier observations, it obviously lacks any statistical or economic rationale.

A last problem with this approach is that the estimates which it produces have no statistical properties. That is, mathematical programming procedures produce estimates without standard errors, t-ratios, and so forth. Basically this is because no assumptions are made about the regressors or the disturbance term in equation *(2.9)* and without some statistical assumptions inferential results cannot be obtained.

The shortcomings of the programming approach have led to the further development of the deterministic statistical frontiers. The statistical frontier models are similar to the deterministic programming frontier model. The deterministic statistical model involves statistical techniques and assumptions to be made about the statistical properties.

Equation *(2.9)* can be made amenable to statistical analysis by introducing some assumptions. Note that the model can be written as:

$$Y = f\,(X)\; e^{-u} \qquad (2.10)$$

or,

$$\ln Y = \ln f\,(X) - u \qquad (2.11)$$

where $u \geq 0$ and thus $0 \leq e^{-u} \leq 1$, and where ln f(X) is linear in the Cobb-Douglas case presented in equation (*2.9*). The question that must be asked is what to assume about X and *u*. The answer that has been given most often is to assume that the observations on *u* are independently and identically distributed, and that X is exogenous. Any number of distributions for *u* could be specified. Aigner and Chu (1968) did not explicitly assume such a model, though it was assumed implicitly. Afriat (1972) was the first to explicitly assume the model. He proposed a two-parameter beta distribution for exp (-*u*), and proposed that the model to be estimated by the maximum likelihood method. Richmond (1974) further considered the model under the assumption that *u* had gamma distribution. On the other hand, Schmidt (1976) has shown that if u is exponential, then Aigner and Chu’s linear programming procedure is maximum likelihood, while their quadratic programming procedure is maximum likelihood if u_i is half-normal. It should be stressed that the choice of a distribution for *u* is important because the maximum likelihood estimates depend on it in a fundamental way-different assumed distributions lead to different estimates. This is a problem because there do not appear to be good a priori arguments for any particular distribution.

A further problem with maximum likelihood in the frontier setting is that the range of the dependent variable (output) depends on the parameters to be estimated, as pointed out by Schmidt (1976). This is because $Y \leq f(X)$ and $f(X)$ involve the parameters to be estimated. This violates one of the regularity conditions invoked to prove the general theorem that maximum likelihood estimators are consistent and asymptotically efficient. As a result, the statistical properties of the maximum likelihood estimators needed to be reconsidered. This is done by Greene (1980) who showed that the usual desirable asymptotic properties of maximum likelihood estimators still hold if the density of u is zero at $u = 0$ and the derivative of the density of u with respect to its parameters approaches zero as u approaches zero. As noted by Greene (1980), the gamma density satisfies this criterion and is thus potentially useful here. However, it is a little troubling that one's assumption about the distribution of technical inefficiency should be governed by statistical convenience.

2.2.3 An Overview of Concept – Adoption

Adoption has variously been defined by a lot of authors. According to van den Ban and Hawkins, (1998) adoption is a mental process through which an individual passes from first knowledge of an innovation to the decision to adopt or reject and to confirmation of this decision. Adoption refers to the decision to use a new technology, method, practice, etc, by a firm, farmer or consumer (Feder *et al*., 1985). Dasgupta (1989) reported that adoption is not a permanent behavior. He further stated that an individual may decide to discontinue the use of an innovation for a variety of personal, institutional or social reasons one of which could be the availability of an idea or practices that is better in satisfying his or her needs. Farmers may hold awareness and knowledge but because of other factors affecting the decisionmaking process, adoption does not occur.

Adoption process is the change that takes place within individual with regards to an innovation from the moment that they first become aware of the innovation to the final decision to use it or not. However, adoption does not necessarily follow the suggested stages from awareness to adoption; trial may not always practiced by farmers to adopt new technology (Ray, 2001). Farmers may adopt the new technology by passing the trial stage. In some cases, particularly with environmental innovations, farmers may hold awareness and knowledge but because of other factors affecting the decisionmaking process, adoption does not occur. It is indicated by Dasgupta (1989) that the decision to adopt an innovation is not normally a single instantaneous act, it involves a process.

Decision-making process as explained by Ray (2001) is the process through which an individual passes from first knowledge of an innovation, to forming an attitude toward an innovation, to a decision to adopt or reject, to implementation of new idea, and to confirmation of the decision. The adoption or rejection of an innovation is the consequence of diffusion of an innovation (Ray, 2001). Diffusion has been defined as a process by which new ideas are communicated to the members of a social system (Rogers and Shoemakers, 1971). An innovation is an idea, method or object which is regarded as a new by an individual, but which is not always the result of recent research (van den Ban and Hawkins, 1998). Diffusion and adoption are thus closely interrelated even though they are conceptually distinct (Dasgupta, 1989).

The adoption pattern to a technological change in agriculture is a complex process. It was found that adoption behavior is related to a large number of personal, situational and social characteristics of farmers. Adopters are characterized by high rate of literacy and higher level of formal education. They also operate large sized holdings, own the land they operate, have a relatively high income and economic status, are commercial in farming operation, have relatively high level of extension contact, and belong to upper socio-economic status categories. Non adopters on the other hand a low rate of literacy and level of formal education, operate smallholdings, are mostly small and marginal farmers, belong to low income group, have a low level of socio-economic status categories (Dasgupta, 1989; Ray, 2001).

Once a new technique of production becomes available, it usually takes sometime before it is fully implemented. At the farm level, the transition period may be characterized by a time lag between awareness of the technology and the actual adoption or by coexistence of the old and new technology. According to (Feder *et al.*, 1985; Feder and Umali, 1993) economic modeling of technology adoption to explain such adoption behaviour has taken different approaches over time.

The early modeling of the 1970s emphasized the impact of information and knowledge on the adoption process and the time lag between awareness and actual adoption (Kislev and Schchori-Bachrach, 1973; Hiebert, 1974). Within the empirical framework, information and knowledge were the intervening variables linking the empirical variables with adoption decisions. Differences in adoption rates were attributed to endogenous factors such as differences in skills (Kislev and Schchori-Bachrach, 1973), risk aversion (Hiebert, 1974) and prior beliefs (Feder and O'mara, 1982). An innovation is conceptualized as first adopted by highly skilled and experimenting farmers and later diffused to low-skilled farmers as experience with the technology accumulated within the community (Kislev and Schchori-Bachrach, 1973). Education, through its positive influence on "the ability to perceive, identify, acquire, process information and respond to new events in the context of risk" (Schultz, 1975), was associated with the early adoption of technologies.

Similarly, risk preferences were identified as the determinant of adoption rate. Early adoption was associated with risk neutrality and late adoption associated with risk aversion (Hiebert, 1974). Learning and information accumulation reduce uncertainty, making the parameters of the production function under the new technology, as perceived by farmers, shift from a low to a high pay-off, thereby persuading the potential adopters who are more risk-averse to also adopt (Hiebert, 1974).

In the light of the uncertainties (i.e. production, price or availability) associated with the new technology, much of the empirical analysis throughout the 1970s and early 1980s focused on the role of risk in the adoption process. Risk aversion reduces adoption because the risk-averse producer stops short of maximizing expected income when the variance of the net income increases as the expected net income increases (Hiebert, 1974). Hence, a risk-averse farmer will trade off high yield (or profit) for low variability so as to reduce the extent of the risk. A range of specifications and decision rules to depict farmer behaviour under risk and uncertainty were proposed and applied. The impact of both the objective and subjective risk was examined.

One widely used approach was that of portfolio selection formulation (Just and Zilberman, 1983), in which optimal decision depends on the mean, variance and covariance structure of the introduced and the locally grown varieties. Under uncertainty, farmers maximize the expected utility of income or profits by choosing the level of variables they control, which can result in partial land allocation to the new technology rather than complete adoption.

In the case of risk neutrality, differences in the adoption rates were attributed to differences in prior beliefs about the new technology (Feder and O'mara, 1981). Adoption of new technology starts with the farmers holding more positive prior beliefs about the profitability of a new technology because they do not need much information to be convinced compared to those who hold less favourable beliefs. With rime, potential adopters update their beliefs about the profitability of the new technology with the new information generated by early adopters and are hence induced to adopt.

Other studies conducted in the 1980s show that farm-to-farm differences in the rate of adoption or extent of adoption of a new technology might be explained by other considerations. Transaction costs involved in learning and acquiring the new technology that are independent of scale were identified as important impediments to the rate of technology adoption (Perrin and Winkelmann, 1976). Because the fixed cost per unit of land decreases in scale, there is a threshold of farm size below which will be high if the sub components are forever changing to adapt to the changing environment or new components being introduced where decision makers have low levels of human capital (Schultz, 1975), as is often the case in developing economies. This critical farm size decreases over time as uncertainty is reduced because of learning and the dissemination of information from early adopters.

Credit constraints were also identified as an impediment to technology adoption in developing economies (Feder *et al.*, 1985). Technologies introduced to increase agricultural productivity are often accompanied by increases in the input requirements, which may not be affordable to some farmers or readily available in specific locations. Even when the technology is neutral to scale and the presumable fixed pecuniary costs not large, credit constraints will limit adoption (Feder *et al.*, 1985). Farmers will allocate land to the new technology up to the point where credit is binding and partial adoption will result.

The impact of complementarities between the interrelated innovations within a package on adoption behaviour was also examined (Feder, 1982), reflecting the way in which innovations were promoted at the time (seed, fertilizer, agronomic practices). Sequential adoption of individual components of a technological package was explained in the light of risk and input scarcity (Byerlee and dePolanco, 1986). Further studies on sequential adoption behaviour were reviewed by Feder and Umali (1993).

Adoption of improved technologies can dramatically improve the well-being of agricultural households, but many questions about the determinants of adoption remain unanswered (Feder, *et al.* 1985; Besley and Case, 1993). McConnell (1983) used production theory where a farmer has an objective to maximize profit; Ellison and Fundenberg (1993) employed a version of innovation diffusion whereas studies such as Swinton and Quiroz (2003a; 2003b) Marra *et al.* (2001), and Norris and Batie (1987) used household model based on utility maximization.

In order to adequately determine factors that influence farmers to adopt improved production technologies, the focus of the adoption analysis needs to go beyond the characteristics of farmers and plots of land (CIMMYT, 1993). A farmer should be regarded as both a producer and a consumer (Sadoulet and de Janvry, 1995). This implies that a farmer takes into consideration "current consumption and production ends" (Readson and Vosti 1997; Clay, *et al.*, 2002), and also policy and physical effects (CIMMYT, 1993.; FAO, 2001a). The consumption needs are satisfied through own production though at times they are met through food purchases. Farmers make purchases using cash from crop sales or off-farm earnings. The need for cash is not only for food but also for other household requirements such as health and education. A farmer may react in a number of ways towards declining production or/and variability in production that undermine consumption needs. Existing practices may be modified or new ones may altogether be adopted (FAO, 2001b). A farmer may here depend on information diffusion from external parties to learn about a new technology (Shaw, 1985; Ellison and Fudenberg, 1993.; Knox, *et al.*, 1998; Marra *et al.*, 2001).

2.2.4 A framework of innovation at farm level

Farm innovation adoption is the introduction of any new or significantly improved technologies or management practices. These include new products, processes, and organisational or marketing systems that have not previously been used on the farm, although they might not be new to the sector or to the world (OECD 2005). Ongoing innovation adoption by growers fundamentally drives productivity growth in the grains industry.

In agriculture, a useful way to conceptualise the pathways through which R&D contributes to productivity is through an innovation systems framework (Nossal 2011; Spielman and Birner2008). Put simply, R&D is undertaken on and off-farm with the expectation of developing new innovations to be diffused to the farm sector (for example, through extension and social networks) and ultimately adopted by farmers. However, the system is far from linear and there is a complex set of interrelated factors that can shape the innovation process.

Farm innovativeness can be measured by ‘innovative effort’, that is, the extent to which a farmer adopts a set of innovations. Innovative effort is determined by farmers’ capacity and willingness to innovate, and the supply of innovations available to them. Characteristics of a farmer, their farm and their operating environment influence whether they have the capacity to adapt and integrate innovations on their farm, and whether they are willing to do so. Given a supply of appropriate innovations ‘on-the-shelf’, these farm-level factors determine the likely effort a farm will contribute to innovation.

Innovative capacity can constraint or facilitate innovation adoption by farmers. It is defined as the ability to effectively adopt innovations. As such, innovative capacity reflects a farmer’s potential for innovation. Farmers with high innovative capacity can better source the outputs of R&D and use them effectively to improve their farm business. A host of farm-level factors can influence innovative capacity in agriculture. Factors such as education, income and farming experience are widely considered to positively affect innovative capacity (Prokopy et al. 2008). These, and other characteristics, give farmers the inherent abilities, information and skills needed for innovation adoption. Conversely, small farm size and limited access to credit are often highlighted as constraints to innovation adoption(Feder et al. 1985).Factors external to farms can also influence innovative capacity, primarily: economic, institutional, environmental, and policy factors. For example, rural extension initiatives can enhance innovative capacity by providing farmers with the requisite knowledge for innovation. Economic factors, such as exchange rates or interest rates, can also improve or inhibit a farmer's capacity to invest in new technologies by directly impinging on their financial means.

However, while innovative capacity is necessary it is not sufficient for innovation adoption to occur. Willingness to innovate also plays an essential role in farm decision-making (Pannell et al. 2006)

A farmer's willingness to innovate also determines their innovation adoption. Willingness relates to a wide range of sociological and psychological factors that can deter (or entice) individual farmers from being innovative or adopting suitable innovations even if they have the capacity to do so. For example, farmers' attitudes to learning and innovation, risk aversion, awareness of innovations, personal goals, values and motivations, and past experiences with innovation adoption can affect whether farmers are willing to innovate.

Like innovative capacity, these sociological or psychological characteristics of farmers can be influenced by farm-level factors (including those of the farmer, their farm and their external operating environment). For example, various demographic (such as age, level of education, family circumstances, attitude to risk, personality) and situational factors (such as farm size, access to credit, participation in off-farm work) can affect farmers' goals and interest in adopting innovations (Marsh 2010; Pannell et al. 2006).

In addition, a farmers' institutional environment can affect the information or incentives they face. Information contributes to the learning process and allows farmers to adjust their perceptions about an innovation to make adoption decisions (Marsh 2010). Incentives can be moral, social or economic and can encourage or discourage farmers to innovate. Financial incentives can be a strong motivator for innovation adoption, although they are not the only consideration.

The third factor determining farmers’ innovative effort is supply of innovations. Adoption relies on the supply of innovations available that are suitable to the farm and have an observable relative advantage. Innovation suitability is an important determinant of innovation adoption. While new technologies are expected to be superior to existing technologies, they are unlikely to be well suited to all farms. The suitability of innovations, and hence the benefits of adoption, vary widely according to characteristics of the innovation, the potential adopter and their existing production technology. The incompatibility of an innovation with current farming systems is often highlighted as a reason that farmers do not adopt some innovations (Feder et al. 1985).The innovations available to the farmer must also have an observable relative advantage to entice adoption. The relative advantage of an innovation relates to its expected benefits in terms of productivity, risk reduction and economic viability. However, farmers also weigh these benefits against other innovation characteristics such as cost, complexity, compatibility and impact on lifestyle. The ability to observe the relative advantage of an innovation, through reliable information, trials or adoption by peers, is important to reducing the complexity and risks associated with innovation adoption (Pannell et al. 2006).

2.2.5 Determinants of Adoption (innovative) Behaviour

Several studies have indicated that the adoption of improved agricultural technologies are affected by many factors such as farm size, age, family size, education, availability of credit, access to information among others (Shiyani et al., 2000; Yishak, 2005; Taha, 2007). Researchers and institutions both within and outside Nigeria have conducted a number of empirical studies on the adoption behaviour of farmers. For ease of clarity the variables often identified as having relationship with adoption of agricultural technologies could be categorized as household personal and demographic variables, economic factors and institutional factors.

Under the personal and demographic variables, the most common household characteristics which are mostly related with farmers' adoption behaviour such as age, gender, education, farming experience has been reviewed. The study conducted by Nkonya *et al*. (1997) on factors affecting adoption of improved maize seed and fertilizer in northern Tanzania, indicated that farmer’s age did not significantly influence improved technology adoption. In contrary, the result of Million and Belay (2004) shows that age has significant but negative influence on the adoption of fertilizers. Shiyani *et al*. (2000) also reported that more the experience of growing chickpea, the higher the adoption of new varieties. Such a pattern is expected because more experienced farmers may have better skills and access to information about improved technologies. Gender differentials are one of the important factors influencing adoption of improved agricultural technologies. Due to long lasted cultural and social grounds in many societies of developing countries, women have less access to household resources and also have less access to institutional services. Regarding the relationship of household’s sex with adoption of agricultural technologies, many previous studies reported that household’s gender has positive effect on adoption in favor of males. For example, in his study on determinants of fertilizer adoption in Ethiopia, Techane (2002) found that male headed households are more likely to adopt fertilizer than female headed households. Similarly, Mulugeta *et al.*(2001), reported that gender differentials among the farm households positively influenced adoption and intensity of adoption of fertilizer use at 5% significance level. They also further mentioned that being a male headed household increases probability of adoption by 5.9%. Studies by Habtemariam (2004), Million and Belay (2004), indicated that farmer’s education had positive and significant influence on adoption. Each additional year of education increases the probability of adoption of improved seed.

Economic variables such as farm size, off- farm activities, live stock ownership influence farmers' adoption behaviour. Concerning farm size the findings of Yishak (2005) reported that farm size exerts a positive influence on adoption of improved technologies. Contrary to this study, Rahmeto (2007) and Taha (2007) reported that land holding was not significant in adoption of improved haricot bean and onion technology package respectively. Off-farm and non-farm activities are the other important activities through which rural households get additional income. The income obtained from such activities helps farmers to purchase farm inputs. Review of some of the past empirical studies shows that the findings regarding the influence of off-farm/ non-farm income on adoption vary from one study to the other. However, majority of the studies reported positive contribution of off-farm and non-farm income to household's adoption of improved agricultural technologies. For instance, different technology adoption studies conducted by Kidane, (2001), Mulugeta *et al.* (2001), Berhanu (2002); and Mesfin (2005) indicated positive relationship between off-farm income and adoption. Contrary to this, Techane (2002) in his study on determinants of fertilizer adoption in Ethiopia reported the negative influence of participation in off-farm income on farmers' adoption of chemical fertilizer. Labour availability is the other important variable which in most cases has an effect on household's decision to adopt new technologies. Several studies reported the positive effect of household labour availability on adoption of improved agricultural technologies. For instance, Million and Belay (2004) in their study on factors influencing adoption of soil conservation measures in southern Ethiopia found positive effect of household's labour availability on adoption of soil conservation measures.

Institutional variables are also having important role in influencing farmers' adoption behaviours. Institutional factors like frequent extension, access to credit, and distance to market among others were found to influence farmers' adoption behaviour. For instance, extension contact is positively related to the adoption decision of farmers. Tesfaye *et al*. (2001) and Habtemariam, (2004) in their study reported that the availability of reliable information sources will enhance communication process and had significant associations with adoption of improved technologies. Tesfaye *et al*. (2001) reported that access to credit had a significant and positive influence on the adoption of improved technologies. To the contrary of this study, Jabbar and Alam (1993) found that access to credit was not significant in their study of adoption rice technology. A study conducted by Degnet (1999) in Mana and Kersa woreda, Ethiopia, showed that the number of oxen owned by a farmer determines maize technology adoption. The study has revealed that availability of off- farm income opportunity and wealth status of the head of household affects adoption of maize technology significantly. Asfaw *et al*.(1997) in Bako area reported that participation of farmers in extension activities (which is represented by farmers attendance at the field days) is the only variable which is found to significantly influence the adoption of improved maize variety. The same study showed that the adoption of fertilizer technology in maize production is influenced positively and significantly by the farmers' use of credit and by the level of formal education of farm household head. Tesfaye *et al*. (2001) conducted a study on the adoption of high yielding maize technology in major maize growing regions of Ethiopia and the results revealed that distance to the nearest market centre, access to credit, significantly and positively influence the adoption decision of improved maize. The study conducted by Taha (2007) and Rahmeto (2007) on adoption of improved onion and haricot bean technology respectively has shown significant relationship to nearest market distance. However Shiyani *et al*. (2000) reported that the distance to market is negatively related to chick pea adoption. Participation in extension training will enable farmers to get more information and improve their understanding about the available packages, which may intern leads to a change in their knowledge, attitude and behavior. According to Kansana *et al*. (1996) and Tesfaye *et al*. (2001), attendance of agricultural training is positively and significantly related to the adoption of improved maize technologies.

2.3 Analytical Framework

2.3.1 The Stochastic Production Frontier

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

According to Forsund *et al.* (1980) this conclusion is reinforced if one considers also the statistical noise that every empirical relationship contains. The standard interpretation is that, first; there may be measurement errors on the dependent variables. Second, the equation may not be completely specified, with the omitted variables individually unimportant. Both of these arguments hold just as well for production functions as for any other kind of equation, and it is dubious at best not to distinguish this noise from inefficiency, or to assume that noise is one-sided. These arguments lie behind the stochastic frontier (also called composed error) model developed independently by Aigner *et al.* (1977) and Meeusen and van den Broeck (1977). The essential idea behind the stochastic frontier model is that error term is composed of two parts. A symmetric component permits random variation of the frontier across firms, and captures the effect of measurement error, other statistical noise, and random shocks outside the firm's control. A one-sided component captures the efforts of inefficiency relative to the stochastic frontier.

An appropriate formulation of a stochastic frontier model in terms of a general production function for the ith production unit can be defined as:

$$Y_i= f(x_i; \beta)\exp(\varepsilon_i) = f(x_i; \beta)+ v_i - u_i \qquad (2.12)$$

Where, v_i is the two-sided 'noise' component, and u_i is the non-negative technical inefficiency component of the error term. The noise component v_i is assumed to be independently and identically distributed (*iid*) as a normal random variable with mean zero and variance σ^2_v, [i.e., $v_i \sim N(0, \sigma^2_v)$], and distributed independently of u_i's which is assumed to be non-negative truncations of the normal distribution with mean, μ, and variance σ^2_u, [i.e., $u_i \sim |N(0, \sigma^2_u)|$], and u, σ^2_u and σ^2_v are unknown parameters to be estimated. The variance of ε is given by $\sigma^2 = \sigma^2_u + \sigma^2_v$. The decomposition of the residual random variable ε_i in the production function *(2.12)* is the decisive property which defines the stochastic frontier production function. The first term, v_i, is a random error which is assumed to be involved in the traditional linear regression allowing for the random variation of production across farms, and captures the effects of statistical noise, measurement errors, and the exogenous shocks beyond the control of producing unit. The second term, u_i, is a non-negative firm effect variable, which is assumed to account for the existence of technical inefficiency of production of the ith firm. Thus the error term $\varepsilon_i = v_i - u_i$ is not symmetric, since $u_i \geq 0$. If $u_i = 0$, production lies on the stochastic frontier and is technically efficient; if $u_i > 0$, production is below the frontier and is inefficient. If the firm effect random term u_i is absent from the model, equation *(2.12)* becomes an average production function used in most efficiency studies. Alternatively, if the random disturbance v_i is absent from equation *(2.12)*, the model reduces to a deterministic frontier estimated by linear programming techniques. Assuming that v_i and u_i are distributed independently of x_i, estimation of equation (*2.12*) by Ordinary Least Squares (OLS) provides consistent estimates of the parameters except β_o, since E(ε_i) = -E(u_i) $\leq$ 0. Furthermore, OLS does not provide estimates for producer-specific technical efficiency. In addition to obtaining estimates of the production technology parameters β in $f\ (x_i;\ \beta)$, the producer-specific inefficiency u_i is the ultimate objective of the estimation. To achieve this objective it is required that separate estimates of the statistical noise v_i and technical inefficiency u_i are extracted from the estimates of ε_i for each producer. This requires distributional assumption on the two error components. Though OLS provides consistent estimates of all production parameters except the intercept term, additional assumptions and a different estimation technique are required to obtain a consistent estimate of the intercept and estimates of the technical efficiency of each producer.

Considering the stochastic production frontier model given in equation (*2.12*), the following distributional assumption is hereby made.

i) $v_i \sim iid\ \mathrm{N}(0,\sigma^2_{\mathrm{v}})$

ii) $u_i \sim iid\ \mathrm{N}^+(0,\sigma^2_{\mathrm{u}})$, that is non-negative half normal.

iii) v_i and u_i are distributed independently of each other, and of the regressors.

The density function of u>0 is given by:

$$f(u)= \frac{2}{\sqrt{2\pi\sigma_u}} \quad exp - \left\{ \frac{2u^2}{2\sigma^2_u} \right\} \tag{2.13}$$

The density function of v is

$$f(v)= \frac{1}{2\pi\sigma_v} \ exp- \left\{ \frac{v^2}{2\sigma^2_v} \right\}, \tag{2.14}$$

Given the independence assumption, the joint density function of u and v is the product of their individual density functions and is given as

$$f(u,v)= \frac{2}{2\pi\sigma_u\sigma_v} exp- \left\{ \frac{u^2}{2\sigma^2_u} - \frac{v^2}{2\sigma^2_v} \right\}, \tag{2.15}$$

Since $\varepsilon = v - u$, the joint density function of u and ε is

$$f(u,\varepsilon)= \frac{2}{\sqrt{2\pi\sigma_u\sigma_v}} \quad exp - \left\{ \frac{u^2}{2\sigma^2_u} - \frac{(\varepsilon+u)^2}{2\sigma^2_v} \right\}, \tag{2.16}$$

The marginal density function of ε is obtained by integrating u out of $f(u,\varepsilon)$ which yields

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

$$= \frac{2}{\sqrt{2\pi}\sigma_u} . \left[1\text{-}\Phi\left(\frac{\varepsilon\lambda}{\sigma}\right)\right]. exp\left\{\frac{\varepsilon^2}{2\sigma^2_u},\right\} \tag{2.17}$$

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

where $\sigma = (\sigma^2_u+\sigma^2_v)^{½}$, $\lambda = \sigma_u+\sigma_v$, and$\Phi[.]$ and $\phi[.]$ are the standard normal cumulative distribution and density functions.

The marginal density function $f(\varepsilon)$ is asymmetrically distributed, with mean and variance

$$E(\varepsilon)=-E(u)=-\sigma_u\left(\frac{2}{\pi}\right)^{½}, \tag{2.18}$$

$$V(\varepsilon)=\frac{\pi\text{-}2}{\pi}\,\sigma^2_u+\sigma^2_v$$

The normal-half normal distribution contains two parameters, σ_u and σ_v.

Aigner *et al*. (1977) suggested [1-$E(u)$] as an estimator of the mean technical efficiency of all producers. However, Lee and Tyler (1978) proposed

$$E(\exp\{-u\}) = 2[1\text{-}\Phi(\sigma_u)].\exp\left\{\frac{\sigma^2_u}{2}\right\}, \tag{2.19}$$

which is preferred to [1-$E(u)$] since [1-u] includes only the first term in the power series expansion of exp{-u}.

The log likelihood function for a sample of N producers is

$$\ln L=-(N/2)(\ln 2\pi+\ln\sigma^2)+\Sigma[\ln\Phi[-\varepsilon_i\lambda/\sigma]-½(\varepsilon_i/\sigma)^2], \tag{2.20}$$

employing the first-order condition of the log likelihood maximization enables an estimation of the frontier parameters. These estimates are consistent as $N\rightarrow+\infty$.

Once the parameters are estimated, the interest centres on the estimation of inefficiency, u_i. Since $E(u_i)$ is a summary measure, it is difficult to decompose the individual residuals into the two components and to estimate the technical inefficiency for individual producers. A solution to the problem is obtained from the conditional distribution of u_i given ε_i, which contains whatever information ε_i contains concerning u_i. Jondrow *et al.* (1982) showed that if $u_i \sim N^+(0,\sigma^2_u)$, the conditional distribution of u given ε is

$$f(u|\varepsilon) = \frac{f(u,\varepsilon)}{f(\varepsilon)}$$

$$= \frac{1}{\sqrt{2}\pi\sigma_*} \exp\left\{-\frac{(u-\mu_*)}{2\sigma^2_*}\right\} \Bigg/ \left[1-\Phi\left(\frac{\mu_*}{\sigma_*}\right)\right], \qquad (2.21)$$

where $\mu_* = -\varepsilon\sigma^2_u/\sigma^2$ and $\sigma^2_* = \sigma^2_u\sigma^2_v/\sigma^2$. Since $f(u|\varepsilon)$ is distributed as $N^+(\mu_*,\sigma^2_*)$, the mean of this distribution can serve as a point estimator of u_i. This is given by

$$E(u_i|\varepsilon_i) = \mu_{*\mathrm{i}} + \sigma_* \left[\frac{\phi(\mu_{*\mathrm{i}}/\sigma_*)}{1-\Phi(-\mu_{*\mathrm{i}}/\sigma_*}\right], \qquad (2.22)$$

$$= \sigma_* \left[\frac{\phi(\varepsilon_i\lambda/\sigma)}{1-\Phi(\varepsilon_i\lambda/\sigma)} - \left(\frac{\varepsilon_i\lambda}{\sigma}\right)\right]$$

Estimates of u_i can be obtained from

$$TE_i = \exp\{-\hat{u}_i\} = \exp\{-E(u_i|\varepsilon_i)\}. \qquad (2.23)$$

Thus far the discussion focused on analysis of stochastic production frontiers on the assumption that $u_i \sim N^+(0,\sigma^2_u)$. This distributional assumption has been employed in empirical work by many authors (Tadesse and Krishnamoorthy, 1997; Seyoum *et al.*, 1998; Yao and Liu, 1998; Ojo and Imoudu, 2000; Amaza and Olayemi, 2002; Amaza and Tashikalma, 2003; Amaza and Maurice, 2005.; Shehu and Mshelia, 2007; Shehu *et al.*, 2007).

2.3.2 Stochastic Frontier Efficiency Decomposition

. The measurement of technical, allocative and economic efficiency can only be handled in a stochastic frontier framework, through the efficiency decomposition technique. The stochastic efficiency decomposition methodology was proposed by Bravo-Ureta and Rieger (1991), which was an extension of the model introduced by Kopp and Diewart (1982) to decompose cost efficiency into technical and allocative efficiency measures. Stochastic efficiency decomposition is generally based on the duality between production and cost functions.

Bravo-Ureta and Rieger (1991) utilize the level of output of each firm adjusted for statistical noise, observed input ratios, and the parameters of the stochastic frontier production function (SFPF) to decompose overall efficiency into technical and allocative efficiency. The parameters of the SFPF are actually used to derive the parameters of the dual cost function.

We begin by assuming that the farm frontier production function can be written as:

$$Y = f\,(X_a; \beta) \qquad (2.24)$$

Where Y is the quantity of output, X_a is a vector of input quantities, and β is a vector of parameters. The technically efficient input vector X_t, for a given level of production Y^*, is derived by solving simultaneously equation (2.24) and the input ratios $X_1/X_i = k_i$ (i > 1), where k_i is the ratio of observed inputs X_1 and X_i at output Y^*.

If the functional form of the production frontier is self-dual, for example Cobb-Douglas, then the corresponding cost frontier can be derived analytically and written in general form as:

$$\mathrm{C} = \mathrm{h}\,(P, Y^*; \gamma) \qquad (2.25)$$

Where C is the minimum cost associated with the production of Y^*, P is a vector of input prices, and γ is a vector of parameters. By using Shephard's Lemma, we obtain:

$$\frac{\partial \mathrm{C}}{\partial P_i} = X_i\,(P, Y^*; \Phi) \qquad (2.26)$$

which is a system of minimum cost input demand equations; where Φ in the equation is a vector of parameters, i = 1, 2,….,N inputs. Substituting a firm's input prices and output quantity into the demand system equation (2.26) yields the economically efficient input vector X'_e. Given a farm's observed level of output, the corresponding technically and economically efficient costs of production are equal to $X_t \cdot P$ and $X'_e \cdot P$, respectively, while the cost of the farm's actual operating input combination is $X'_a \cdot P$. These three cost measures are the basis for computing the following technical (TE) and economical (EE) efficiency indexes:

$$\mathrm{TE} = (X_t \cdot P) / (X'_a \cdot P) \qquad (2.27)$$

and

$$\mathrm{EE} = (X'_e \cdot P) / (X'_a \cdot P) \qquad (2.28)$$

Following Farrell (1957), equations *(2.27)* and *(2.28)* can be combined to obtain the allocative efficiency (AE) index:

$$\mathrm{AE} = (\mathrm{EE}) / (\mathrm{TE}) = (X'_e \cdot P) / (X_t \cdot P) \qquad (2.29)$$

2.3.3 Empirical Application of Production Frontiersin Efficiency Studies

Stochastic frontier production function has been applied in a considerable number of empirical studies in the field of agriculture. A brief survey of some of these studies is presented below:

The first application of the stochastic frontier model to farm-level agricultural data was presented by Battese and Corra (1977). They found that the variance of the farm effects was highly significant proportion of the total variability of the logarithm of the value of sheep production in Pastoral Zone of Australia. The γ-parameter estimates exceeded 0.95 in all the areas surveyed.

Kalirajan (1981) estimated a stochastic frontier production function on rice farmers for the rabi season in a district of India. He found that the variance of farm effects was highly significant component in describing variability of rice yields (the estimated γ-parameter was 0.81). He proceeded to investigate the relationship between differences between the estimated yield function and the observed rice yields and such variables as farmer's experience, educational level, number of visits by extension workers, etc.

Bagi (1982) used the stochastic frontier Cobb-Douglas production function model to determine whether there were any significant differences in the technical efficiencies of small and large crop and mixed-enterprise farms in West Tennessee. His findings indicated that variability of farm effects was highly significant, and the mean technical efficiency of mixed-enterprise (0.76) was smaller than that for crop farms (0.85).

However, there did not appear to be significant differences in mean technical efficiency for small and large farms, irrespective of whether the farms were classified according to acreage or value of farm sales.

Kalirajan and Shand (1986) investigated the technical efficiency of rice farmers within and without the Kemubu Irrigation Project in Malaysia during the 1980 using translogarithmic stochastic frontier production function. They reported that the individual technical efficiencies ranged from 0.40 to 0.90, such that the efficiencies for those outside the project were slightly narrower. They concluded from their findings that the introduction of new technology for farmers does not necessarily result in significantly increased technical efficiencies over those for traditional farmers.

Dawson and Lingard (1989) employed a Cobb-Douglas stochastic frontier production function to estimate technical efficiencies of Philippine rice farmers using four years data. The results from the four stochastic frontiers indicated that there were significantly different from the corresponding deterministic frontiers. The technical efficiencies ranged between 0.10 and 0.90, with the means between 0.60 and 0.70 for the four years involved.

Rola and Quintana-Alejandrino (1993) used a Cobb-Douglas stochastic frontier production function to estimate the technical efficiencies of rice farmers in different rice environments in selected regions of the Philippines. The estimated mean technical efficiencies were found to be 0.72, 0.65 and 0.57 for irrigated, rain-fed and upland environments, respectively, indicating high variability in the technical efficiency estimates between the different rice environments. The further reported that education, access to capital and land tenure status were some factors that affected the levels of technical efficiencies of farmers in the different environments.

Seyoum, *et al.* (1998) investigated the technical efficiency of two samples of maize producers in Eastern Ethiopia, one involving farmers within Sasakawa-Global 2000 project and the other involving farmers outside the project. They found that Cobb-Douglas stochastic frontiers were adequate representations of the data. The empirical results indicated that farmers within the SG 2000 project were more technically efficient than those outside the project relative to their respective technologies (0.937 versus 0.794, respectively).

Obwona (2000) applied the Cobb-Douglas stochastic frontier production function to study the determinants of technical efficiency differentials among small and medium tobacco farmers in Uganda. The results indicated that education, credit accessibility and extension services contributed positively to the improvement of efficiency of the farmers.

Weir and Knight (2000) used stochastic frontier production function to study the impact of education externalities on production and technical efficiency of farmers in rural Ethiopia. They found that the source of externalities to schooling was in the adoption and spread of innovations which shift out the production frontier. The further stated that the mean technical efficiency of cereal crop farmers was 0.55, and a unit increase in years of schooling increases technical efficiency by 2.1%.

Ajibefun and Aderinola (2003) applied translog stochastic frontier production function to study determinants of technical efficiency in traditional agricultural production in Nigeria. The results indicated that the mean technical efficiency of farmers under pure stand was significantly greater than that from multiple cropping systems. Also, the found that level of education, years of farming experience, extension visit, fertilizer use, system of land ownership and membership of cooperative societies significantly influence the levels of technical efficiency of the farmers.

Amos, *et al.* (2004) used a Cobb-Douglas stochastic frontier production function to study productivity and technical efficiency of farmers in Niger State of Nigeria. They found that that mean technical efficiency of farmers was 0.62, but the mean technical efficiency of sole maize farmers (0.53) was lower compared to that of the mixed (yam/maize) cropping system (0.72). They further reported that over 50% of the mixed crop farmers had technical efficiency greater than 0.70 as compared to 100% sole farmers who had less than 0.60 level of technical efficiency.

Amaza and Maurice (2005) investigated the factors that influence technical efficiency in rice-based production systems among ‘*Fadama*’ farmers in Adamawa State, Nigeria using Cobb-Douglas stochastic frontier production function. The finding indicated the years of farming experience and level of education significantly affect farmers’ efficiency levels.

Shehu *et al.* (2007) applied the Cobb-Douglas stochastic frontier production function to study technical efficiency among rain-fed upland rice farmers in north-west agricultural zone of Adamawa State, Nigeria. The empirical results indicated that more than 88% of the sampled farmers attained greater that 80% technical efficiency level. They further reported that farming experience, household size and level of educational attainment reduces technical inefficiency of the farmers.

The stochastic efficiency decomposition technique has also been applied by a couple of authors to estimate the technical, allocative and economic efficiency of farmers. For example, Xu and Jeffrey (1998) obtained significantly lower technical, allocative, and economic efficiency indices for hybrid rice production in China as compared with conventional rice production across all the three regions studied. Singh *et al.* (2000) obtained lower technical, allocative and economic efficiency for newly established Indian dairy processing plants after liberalization of the dairy industry compared to the old plants as they needed time to reach full operation, the right choice of products and other managerial skills for higher performance.

Ali and Chaudhry (1990) estimated the mean technical, allocative and economic efficiency measures for crop production in Pakistan at 84, 61 and 51 percent, respectively, while the corresponding measures for dairy farms in the USA were 83, 85 and 70 percent (Bravo-Ureta and Rieger, 1991). Also, it was reported that the technical, allocative and economic efficiency measures for crop-livestock farmers in Brazil were 17, 74 and 13 percent, respectively (Taylor *et al.*, 1986), while the corresponding estimates for swine producers in Hawaii were 75.9, 80.3 and 60.3 percent, respectively (Sharma *et al.*, 1999). Bravo-Ureta and Evenson (1994) obtained the three measures for cotton and cassava production. The average technical, allocative and economic efficiency measures for cotton production were 58, 70 and 40 percent, respectively, while the corresponding figures for cassava were 59, 88 and 52 percent respectively. In their study in the Dominican Republic, Bravo-Ureta and Pinheiro (1997) reported average levels of technical, allocative and technical efficiency equal to 70%, 44% and 31% respectively. These results according to them suggest that substantial gains in output and/or decrease in cost can be attained given existing technology. Singh *et al.* (2000) also obtained average technical, allocative and economic efficiency measures, respectively, of 86.7, 84.4 and 72 percent for Indian private dairy processing plants while the corresponding figures for the cooperative dairy processing plants were 87.4, 90.4 and 78.8 percent, showing that the new private dairy processing plants were less efficient than the old cooperative plants. All these studies indicated the existence of considerable potential within the farms to increase production through improved technical, allocative and economic efficiency. In a more recent study, Ogundari and Ojo (2006) obtained a mean TE, EE and AE of 0.90, 0.89 and 0.81 respectively among smallholder cassava farmers in Osun State of Nigeria.Okoruwa *et al.* (2006) investigated the technical, allocative and economic efficiencies for a sample of rice farmers in North Central Nigeria.

2.3.4 Logistic Regression

The use of qualitative response models in explaining discrete decision making is well documented (Agada and Philip, 2002). The simplest of these models, the linear probability model (LPM) is amenable to the OLS method. However, it suffers the limitations that its disturbance term is potentially heteroschedastic and the model's probability predictions are not necessarily bounded within (0, 1) (Pindyck and Rubinfeld, 1997). Two transformations of the LPM which bounds probability values within (0, 1) are the Logit and Probit models. There is no clear theoretical or empirical preference between Logit and Probit models. Both of them transform LPM monotonically to preserve the direction of influence of the regressors or factors on the decision variable. The two models are based on cumulative probability functional transformations; with the probit assuming normality while the Logit assumes logistic functional form (Gujarati, 2006).

The first step in the application of Logit model is the specification of the dependent and explanatory variables. The specification of the general form requires the variable to be explained (dependent variable) hypothesized as a function independent variable. Mathematically, the Logit model can be stated thus:

$$\ln\left(\frac{\phi_i}{1-\phi_i}\right) = \beta_o + \Sigma\beta_j X_{ij} + \varepsilon_i \qquad (2.30)$$

Where, $\left(\frac{\phi_i}{1-\phi_i}\right)$ is "odd", $\left(\frac{\phi_i}{1-\phi_i}\right)$ is the logarithm of "odds", j is the response category

(1 or 0), *i* denotes cases (1, 2,……, n), ϕ is the conditional probability, β_o is the coefficient of the constant term, β_j is the coefficient of the independent variable, X_{ij} is the matrix of observed values, and ε_i is the matrix of unobserved random effects.

Equation *2.30* can be manipulated to give the odds ratio as follows:

$$\frac{\phi_i}{1-\phi_i} = \exp\left[\beta_o + \Sigma\beta_j X_{ij}\right] \qquad (2.31)$$

The probability that a farmer adopts an improved technology can be calculated thus:

$$\phi_i = \frac{\text{Exp}\left[\beta_o + \Sigma\beta_j X_{ij}\right]}{1 + \text{Exp}\left[\beta_o + \Sigma\beta_j X_{ij}\right]} \qquad (2.32)$$

Equation 2.32 is intrinsically linear since the Logit is linear in X_i (Gujarati, 2004); it indicates that probability ϕ_i lies between zero and one and vary non-linearly with X_i.

The coefficients in Logit analysis are estimated using maximum likelihood. The interpretation of the coefficients is not as straight forward as in ordinary least square regression analysis. The coefficients on their own do not tell much but the coefficients can be used to compute the marginal effects, which are useful in interpreting the effect of predictors on the change of probability. Also the signs of the coefficients can be used to indicate the direction of the change of the predicted probability arising from a change in the predictor.

The main interest for any analyst is to know what the effect of a change in a given predictor would be on the outcome. The marginal effect on the probability for an average individual due to a small change in variable X_k under a logistic distribution is

$$\frac{\partial\phi_i}{\partial x_i} \quad \phi_i\,(1 - \phi_i)\beta_j \qquad (2.33)$$

Equation *2.33* cannot be used to evaluate the incremental effects of a dummy variable. The effect of a dummy variable has to be analyzed by comparing the effect of the variable when the value is one to when the value is zero. The difference of the effects on the probabilities between the two values, holding other variables constant, is the incremental effect for a dummy variable. As much as the marginal effects can be computed on an individual case by case, the general practice is to compute the marginal effects at the sample's mean values.

The likelihood ratio test is used to see if the model including regressors provides extra explanatory power over the model with only an intercept. The likelihood ratio statistic is computed based on the premise that there are two models. Assuming that the unrestricted model has the log-likelihood function denoted as L_1 and the restricted model has the log-likelihood function denoted as $L_{2,}$ the likelihood ratio test of the hypothesis of dropping all regressors is defined as $2(L_1 – L_2)$. The degree of freedom is equal to the number of the estimated coefficients less one (i.e. the intercept is excluded). The computed likelihood ratio statistic has an asymptotic chi-square distribution. Therefore, the computed statistic is compared with the critical value in the chi-square table. If the estimated statistic is greater than the table chi-square value, then the variables in the estimated model jointly explain the response effect. It means the hypothesis to drop all variables apart from the constant term is rejected by data.

Like the likelihood ratio test, the pseudo R-Squared is based on comparing a model with regressors to a model with only a constant intercept. It can be used to determine the goodness of fit in a limited sense. A pseudo R-Squared of one indicates a perfect fit whilst zero means that all the coefficients are zero hence regressors do not contribute to any variation of the dependent variable. The values of pseudo R-Squared between zero and one do not have any natural interpretation (Mukherjee*et al.*, 1998).

Empirical application of the logit model has been employed by several authors (Agada *et al.*, 1997; Batz, Peters and Jansen, 1999; Agada and Philip, 2002; Alamu and Aminu, 2003; Adeoti and Egwudike 2003; Rahman and Alamu, 2003; Dawang *et al.*, 2007; Opia and Oyaide, 2007; Bamire *et al.*, 2007).

CHAPTER THREE
METHODOLOGY

3.1 The Study Area

The study area is North-Eastern Nigeria. It comprised of six (6) States namely: Adamawa, Bauchi, Borno, Gombe, Taraba and Yobe (Figure 3.1). The area lies between Latitudes $7^0 30^/$ and 14^0 North of the equator and between Longitudes 9^0 and 15^0 East of the Greenwich Meridian. It shared boundaries with Cameroon and Chad Republics to the east, Taraba, Benue and Plateau States to the south, Jigawa and Kano States to the west and Niger Republic to the North. The number of inhabitants of the area was put at 18,971,965 based on the 2006 census (Federal Republic of Nigeria, FRN, 2007). The mean annual rainfall in the area ranges from 250mm around Nguru (Borno State) to about 1310mm around Sugu (Adamawa State), while mean annual temperature ranges from 20^oC to 40^oC (NAERLS/PCU, 2004). Growing season in the study area lasts between 2 months in the northern part to about 5½ months in the southern part of the area. Major crops grown in the area include Rice, Maize, Millet, Sorghum, Cowpea, Cotton, Groundnut, Yam, Potato, Cassava and Water melon (Ojanuga, 2006). The major occupations of the inhabitants of the area include farming, fishing, trading, weaving, dyeing and gathering. Infrastructures such as road networks, electricity, schools and institutions, hospital are found in the area.

3.2 Sampling Techniques

Purposive and Multi-stage random sampling techniques were used to select respondents for this study (Figure 3.2). In the first stage, three States were purposively selected based on their relative importance in rain-fed rice production. They are: Adamawa, Gombe and Taraba states (Figure 3.3). The second stage involved the selection of 10 local government areas (LGAs) proportional to the number of LGAs in selectedstates. The proportionality factor used is stated thus:

$$X_i = {}^{n}/N*10$$

Where X_i= number of LGAs sampled in each state

n=number of LGAs in a particular state

N= Total number of LGAs in all the selected states

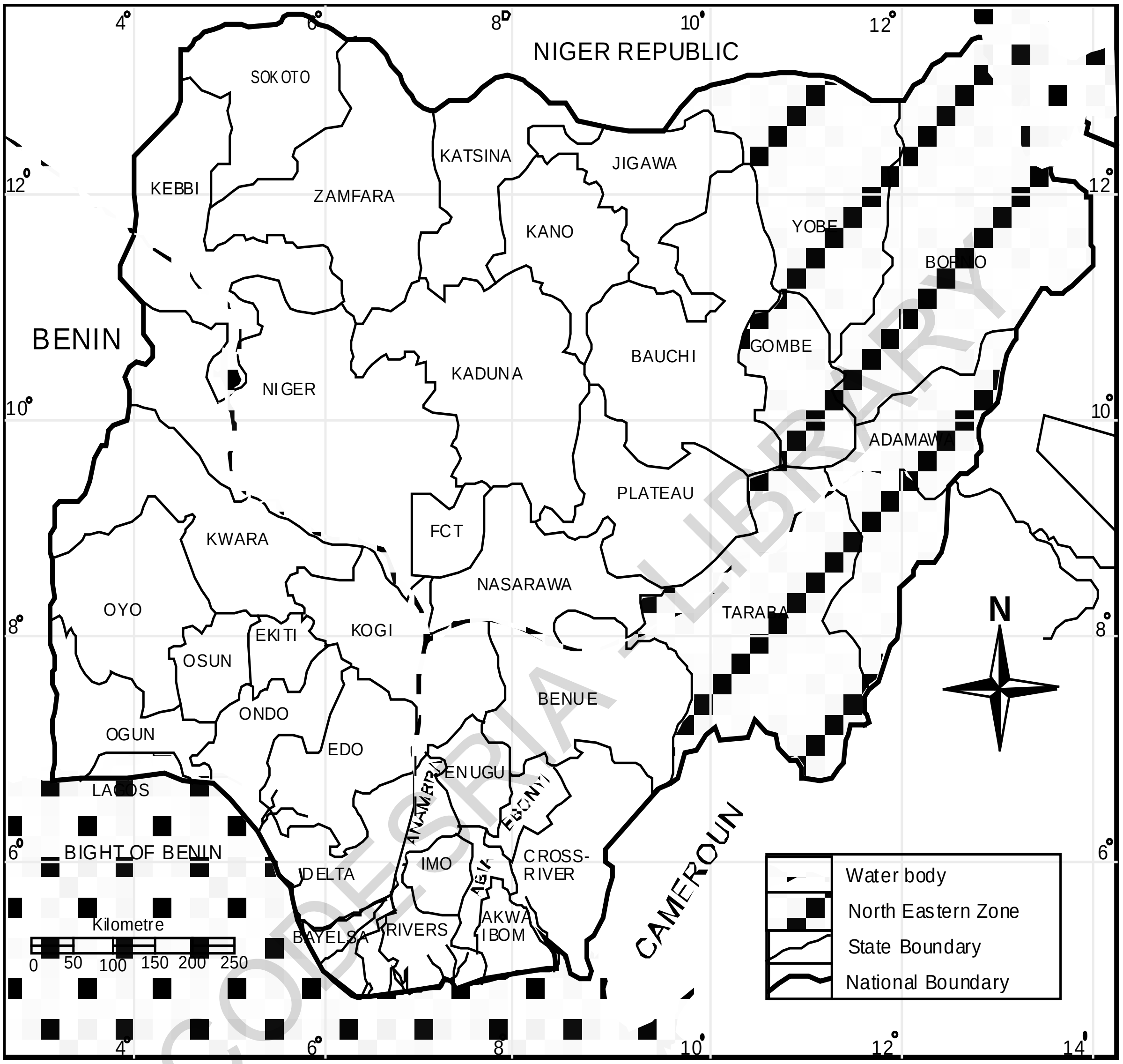
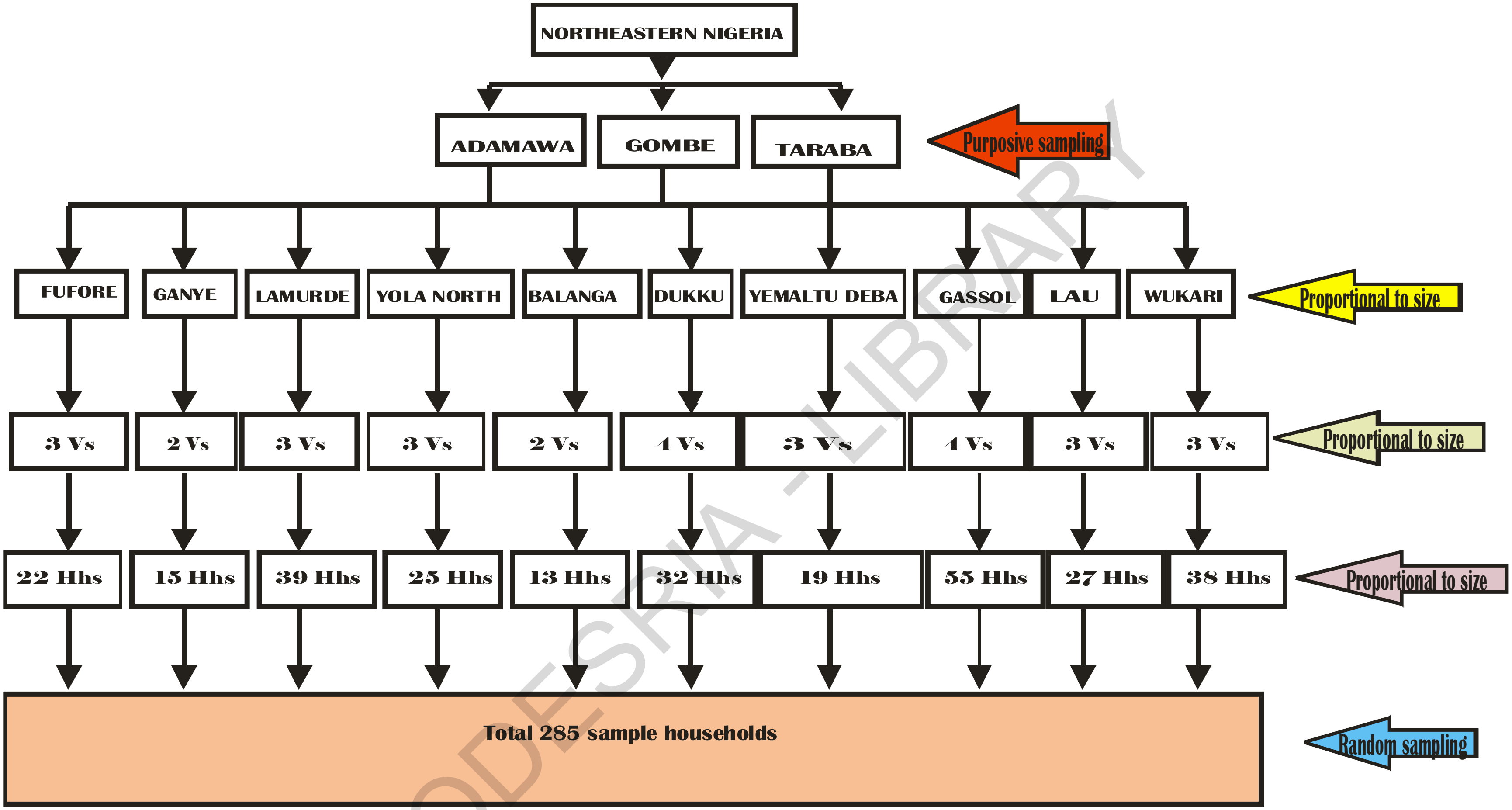


FIGURE 3.1: MAP OF NIGERIA SHOWING NORTH-EASTERN REGION



Vs stands for villages
Hhs stands for households

Fig. 3.2: Sampling procedure

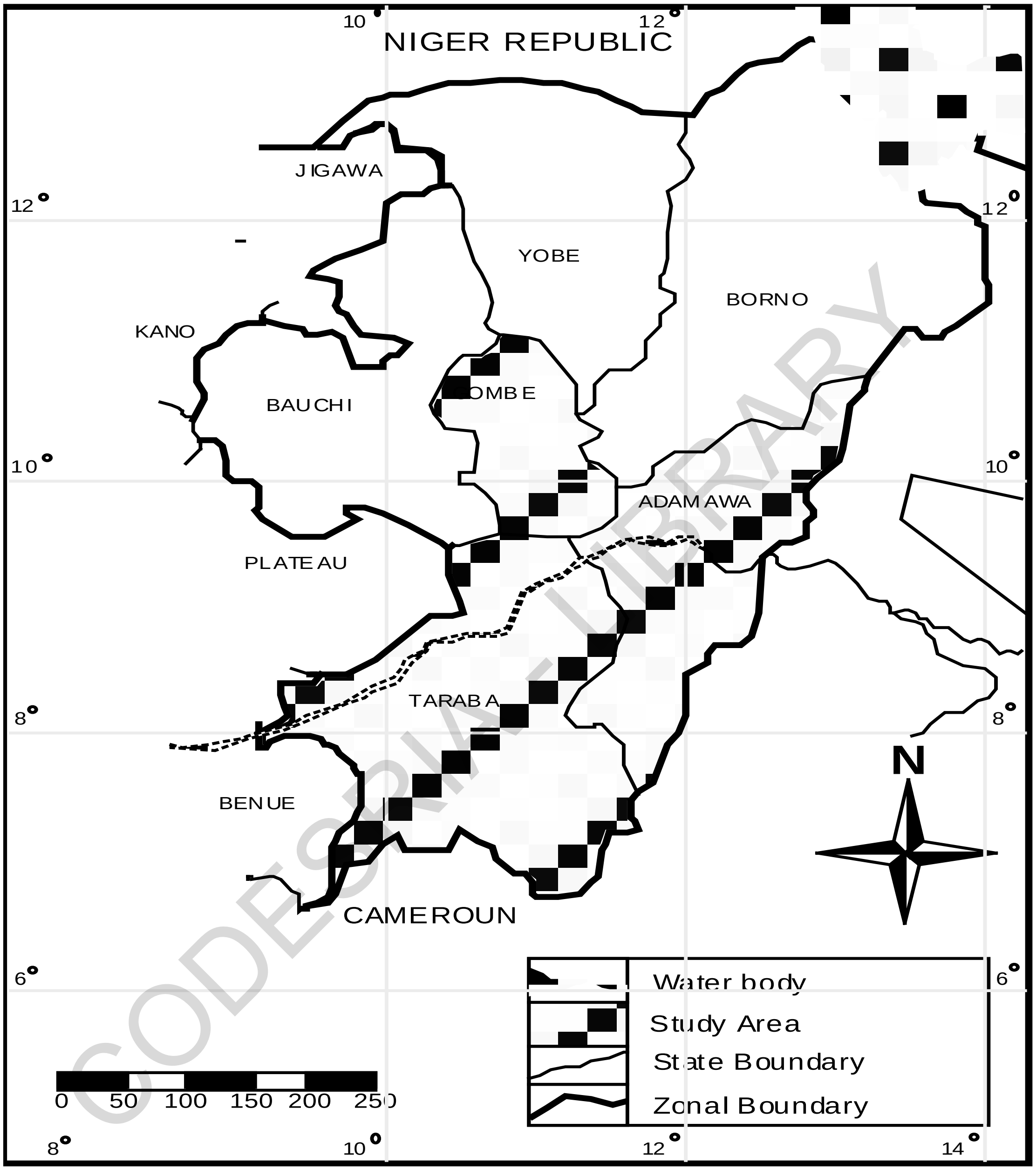


FIGURE 3.3: MAP OF NORTHEASATERN NIGERIA AREA SHOWING THE SELECTED STATES

In the third stage, thirty (30) villages were selected using another proportionality factor such that the number of villages selected from each LGA is proportionate to the total number of LGAs in all the States. The proportionality factor used is stated thus:

$$X_j = {}^{p}/P*30$$

Where X_j= number of villages sampled in each LGA

p=number of villages in a particular LGA

P= Total number of villages in all the selected LGAs

In the three stages above, total selected of states, LGAs and villages was based on their relative importance in rain-fed rice production. In the final stage 285 rice farmers (Table 3.1) were randomly selected from the selected villages in a ratio proportional to the size of the population of farmers who cultivate rice on sole basis. However, only 270 were used for analyses. The remaining 15 were rejected due to inconsistencies in the responses. Information on the population of the rice farmers was obtained from the various States' Agricultural Development Programmes through agricultural extension agents working in the selected villages.

3.3 Data Collection

Data for this study was collected from the selected paddy rice farmers on their household production activities during the 2010/2011 cropping season. The data was collected with the use of interview schedule. The interview schedule (appendix 1) was designed to collect information on output of paddy rice and production inputs including their respective prices as well as socio-economic attributes of the sampled farmers. Data on inputs was collected on a fortnightly basis by asking farmers to recall their activities during the past two weeks. To facilitate the collection of the data, the services of the agricultural extension agents in the selected areas were engaged. The extension workers were believed to have good experience in terms of relaying the relevant information to the respondents and have good communication ability. One week intensive training was given to the extension workers to make them acquainted with the questionnaire. The extension agents were assumed to have understood the language, culture and tradition of the areas; hence there will be no barrier to communication with the households.

Table 3.1: Number of rice farmers selected from the study area

Selected States	Total number of LGAs	Selected Local Government Areas	Selected Villages	Sampling frame	Number of farmers randomly selected
Adamawa	21	Fufore	i. Chikito	30	10
			ii. Dasin	20	7
			iii. Gurin	15	5
		Ganye	i. Buwangal	20	7
			ii. Sugu	25	8
		Lamurde	i. Gyawana	35	12
			ii. Tingno Dutse	50	17
			iii. Waduku	30	10
		Yola North	i. Bachure	25	8
			ii. Bwaranji	20	7
			iii. Jambutu	30	10
Gombe	11	Balanga	i. Gelengu	17	6
			ii. Wadaci	20	7
		Dukku	i. Bayan Dutsi	20	7
			ii. Hashidu	30	10
			iii. Pakkar	25	8
			iv. Nyolel	22	7
		Yemaltu Deba	i. Dadin Kowa	25	8
			ii. Garin Sarki	18	6
			iii. Kwadon	14	5
Taraba	16	Gassol	i. Gassol	48	16
			ii. Kwatan Taro	35	12
			iii. Mutum Biyu	42	14
			iv. Tella	40	13
		Lau	i. Abbare	35	12
			ii. Kunini	26	8
			iii. Lau	22	7
		Wukari	i. Bantaje	46	15
			ii. Gindin Dorowa	40	13
			iii. Rafin Kada	30	10
TOTAL	**48**	**10**	**30**	**855**	**285**

3.4 Analytical Techniques

With the aim of achieving the objectives of the study stated in chapter one, and in line with the analytical framework, descriptive statistics, stochastic frontier production and cost functions, two-limit tobit regression and binary logistic regression were used as analytical tools.

3.4.1 Empirical Stochastic Frontier Model.

The choice of functional form in an empirical study is of prime importance, since the functional form can significantly affect the results. A flexible functional form is generally preferred, since it does not impose general restrictions on the parameters nor on the technical relationships among inputs. In this study therefore, the production technology was assumed to be characterized by a Cobb-Douglas production function. The specification is admittedly restrictive in terms of the maintained properties of the underlying production technology. However, as interest rests on efficiency measurement and not on the analysis of the general structure of the production technology, the Cobb-Douglas production function is assumed to provide an adequate representation of the production technology (Taylor *et al*., 1986; Battese, 1992). Further, self-dual nature of the Cobb-Douglas production function and its cost function provide a computational advantage in observing estimates of technical and allocative efficiency.

For the investigation of technical, allocative and economic efficiency, a stochastic frontier production function of the following form was estimated.

$$\ln Y_i = \beta_o + \Sigma\beta_i \ln X_{ij} + \varepsilon_i \qquad (3.1)$$

where Y_i=paddy output in kilogram of the ith farmer, X_{ij} are the inputs used (land (ha), seed (kg), family labour (mandays), hired labour (mandays), fertilizer (kg) and herbicide (litres)) ln=natural logarithm, ε_i = error term, β_i= parameters to be estimated, β_o= constant.The error term ε_i is defined as:

$$\varepsilon_i = v_i + u_i \qquad 3.2$$

The random variables ν_{i} and u_i in model (*3.2*) are assumed to have the properties specified for the corresponding unobservable random variables in the frontier production function model (*2.12)*.

Now, let σ^2_u and σ^2_v be the variances of the parameters one sided (u_i) and systematic (v_i). Therefore,

$$\sigma^2 = \sigma^2_u + \sigma^2_v \qquad 3.3$$

and the ratio of the two standard errors as used by Jondrow *et al*. (1982),

$$\lambda = \sigma_u / \sigma_v \qquad 3.4$$

Or

$$\gamma = \sigma^2_u / \sigma^2 \qquad 3.5$$

is defined as the total variation of output from frontier which can be attributed to technical efficiency (Battese and Corra, *1977.*). Furthermore, given a multiplicative production frontier for which Cobb-Douglas function equation (*3.1*) was specified, the farm-specific technical efficiency (TE_i) of the i^{th} farmer was estimated by using the expectation of u_i conditional on the random variable ε_i as shown by Battese and Coelli (1988). That is,

$$TE_i = exp\,(-u_i) \qquad 3.6$$

so that, $0 \leq TE_i \leq 1$.

Given functional and distributional assumptions, maximum-likelihood estimates (MLE) for all parameters of the stochastic frontier production defined by equations (*3.1*), the variance parameters defined by equations (*3.3*) and (*3.5*), and the technical efficiency defined by equation (*3.6*) was simultaneously estimated using the program, FRONTIER 4.1 (Coelli, 1996).

The dual cost frontier which was derived analytically from the stochastic production frontier is specified as follows:

$$\ln C_i = \beta_o + \beta_R \ln L_R + \beta_S \ln P_S + \beta_{FL} \ln W_{FL} + \beta_{HL} \ln W_{HL} + \beta_F \ln P_F + \beta_H \ln P_H + \beta_Y \ln Y_k \qquad 3.7$$

where, Ci per farm cost of producing rice, L_R is the seasonal rent on land, P_S price of seed, W_{FL} is the wage rate of family labour used, W_{HL} is expenses on hired labour used, P_F is total amount of money spent on the purchase of fertilizer, P_H is total amount of money spent on the purchase of herbicide, and Y_k is total rice output in kilogram of the k^{th} farm.

However, it should be noted that the FRONTIER computer programme estimates the cost efficiencies (CE), which is computed originally as the inverse of equation 2.28. Hence, farm-level economic efficiency (EE) was obtained using the relationship

$$EE = 1/\text{ Cost efficiency (CE)} \qquad 3.8$$

i.e EE is the inverse of CE (Coelli *et al.*, 1998)

Following the estimation of technical, allocative and economic efficiency measures, a second stage analysis involved a regression of these measures on several hypothesized socio-economic and institutional factors affecting efficiency of farmers. It has become a standard practice in efficiency analysis to include only the conventional inputs (i.e. land, labour, seed, fertilizer and other variable inputs) in the frontier production function. It is argued that the non-conventional inputs such as education, credit, experience, etc., influence output indirectly by raising efficiency with which the conventional inputs especially land and labour are used (Alene, 2003). Therefore, the non-conventional inputs were used in the second stage analysis of factors influencing production efficiency.

Although few authors (e.g. Kumbhakar, 1994; Battese and Coelli, 1995) challenge the approach by arguing that the farm-specific factors should instead be incorporated directly in the first stage estimation of the stochastic frontier, many justify the two-stage method in that the variable can only have a roundabout effect on efficiency (Bravo-Ureta and Rieger, 1991; Bravo-Ureta and Evenson, 1994; Bravo-Ureta and Pinheiro, 1997; Sharma *et al*., 1999; Alene, 2003).

For policy purposes, the identification of factors influencing efficiency has also been an important exercise but the debate as to whether a single or two-stage method is appropriate is not yet settled. Although few authors (e.g. Kumbhakar, 1994; Battese and Coelli, 1995) challenge the approach by arguing that the farm-specific factors should instead be incorporated directly in the first stage estimation of the stochastic frontier, many justify the two-stage method in that the variables can only have a roundabout effect on efficiency (Bravo-Ureta and Rieger, 1991; Bravo-Ureta and Evenson, 1994; Sharma *et al.*, 1999; Alene, 2003).

To delve deeper into this matter, and based on the literature, the following models of investigating the relationship between farm/farmer characteristics and the predicted technical, allocative and economic efficiency indices were estimated.

$$Effic = f\,(AGE, PEO, EDU, EXT, ASSO, CREDIT, TEN) \qquad 3.9$$

where, *Effic* is alternatively, the farm-level of efficiency (technical, allocative and economic). The explanatory variables in equation (*3.9*) as explained in Table 3.2 were used as determinants of production efficiency of the farmers. The natural logarithms of the variables were used. These variables and many others were often hypothesized to influence efficiency in Nigerian context (Ajibefun and Aderinola, 2003; Shehu *et al*., 2007).

The models for efficiency in equation (*3.9*) are estimated separately using the two-limit Tobit model procedure, given that the efficiency indices are bounded between 0 and 1(Binam *et al*., 2005).

3.4.2 The empirical Tobit model

The two-limit Tobit is written as follows:

$$Effic_i^* = \beta' X_i + u_i \qquad 3.10$$

Where $Effic_i^*$ is the latent value of efficiency scores. If the observed value of efficiency score is denoted by *Effic*, then

$$Effic_i = L_{1i}, \text{ if } Effic_i \leq L_{1i}$$

$$= Effic_i^*, \text{ if } L_{1i} < Effic_i^* \leq L_{2i} \qquad 3.11$$

$$= L_{2i}, \text{ if } Effici > L_{2i}$$

Where L_{1i} and L_{2i} are, respectively, the lower and upper limits: that means 0 and 1. The X_i^s are the determinants of efficiency defined in equation *3.9*, while u_i are identically and independently distributed random error N (0, σ²).

Table 3.2Description of variables in the tobit model

Variable	Variable code	Description and unit	*a priori* expectation
Age of farmers	AGE (X_1)	Age of household's decision maker (years)	+/-
Household size	PEO (X_2)	Number of persons in the family (number)	+/-
Education	EDU (X_3)	Level of formal education of household's decision maker (years)	+
Extension contact	EXT (X_4)	Visit by extension agent (number of visit)	+
Membership of cooperative society	ASSO(X_5)	Registered member of a co-operative society; (dummy, yes, 1, No, 0)	+
Access to credit	CREDIT (X_6)	Obtained loan to finance rice farming (Yes, 1; No, 0)	+/-
Land Tenureship	TEN (X_7)	System of land ownership (dummy, owned = 1, 0 otherwise	+

A priori expectations of the factors that affects farmers' efficiency

The contribution of age in enhancing efficiency is somewhat controversial. The sign on the coefficient of age could be negative or positive. If older farmers were not willing to adopt better practices whereas younger farmers are motivated to embrace better agricultural production practices that reduce technical inefficiency effects, then the coefficient would be positive (greater technical efficiency). However, if older farmers have more experience and knowledge of the production activities and are more reliable in performing production tasks, then the coefficient would be negative.

The coefficient of household size could be negative and positive. The coefficient associated household size is expected to be positive if the ratio of adult members of a household is high. More adult members in a household mean more quality labour is available for carrying out farming activities in a timely fashion, therefore making the production process more efficient. However, if adults constitute low proportion in a household then the coefficient will be negative.

The coefficient of education is expected to have a positive sign because a higher level of educational attainment would result in lower inefficiency. The educational attainment of the farm manager is a proxy for human capital.

Extension contact is expected to have a positive coefficient. Access to extension service afford farmers the opportunity to have access to better production methods as well as receive training on how best to combine resources for higher productivity and efficiency. Therefore, the more the contact times the better the tendency of increased efficiency.

Membership of association is expected to assist farmers to get easy access to credit facilities and other production inputs. It can also enhance access to technological information which invariably helps farmers improve their efficiency in production. The sign of the parameter of this variable is hypothesized to be positive.

Access to credit is expected to assist farmers purchase necessary inputs for crop production. Also, it gives farmers additional resources of investment in new ideas. However, credit could be accessed but not utilized judiciously. This could impact negatively on efficiency. Therefore, the sign could be positive or negative.

The coefficient of system of land ownership is expected to be positive. If farmers own land which is sizeable enough they are likely to use part of it to try improved production techniques transferred to them. By so doing they become conversant with the new technologies which will in turn leads to specialization and thus increased inefficiency.

3.4.3 The empirical Logit Model

The Logit model was used to achieve objective 4 of the study. The empirical model is specified thus:

$$(Y_i = 1/X_{ij};\ j = 1 \text{ to } 8) = F\ (Z_i) = 1/1+e^{-zi} = e^z/e^z + 1;\ i = 1 \text{ to } 270 \qquad 3.12$$

Where $Z_i = (\alpha, \beta_1 X_1, \beta_2 X_2, \ldots\ldots, \beta_8 X_8, \varepsilon)$

F(.) = Cumulative logistic function

Z_i is a theoretical or unobserved or an unobservable variable, that is, although X_i's was generated from the field, the β_i's are not observable. In order to obtain the values of Z_i, the likelihood of observing the sample needs to be formed by introducing a dichotomous response variable Y_i such that

$$Y_i = \begin{cases} 1 \text{ if the } i^{th} \text{ farmer is adopter of modern rice production technology *} \\ 0 \text{ if the } i^{th} \text{ farmer is non-adopter of modern rice production technology} \end{cases}$$

X_{ij} is the j^{th} socio-economic and institutional attributes of the i^{th} farmer as contained in Table 3.3

B_1 to β_8 are parameters to be estimated

α = constant term

ε = disturbance term assumed to have zero mean and constant variance.

*** Measuring innovative behaviour**

The measure of innovative effort developed for each farm was based on the number and extent of innovations (production recommendations) that each farmer had adopted (during the 2010/2011 cropping season). Given that nearly all the farmers had adopted partially or fully at least one innovation (improved seed varieties, fertilizer, herbicide and/or insecticide), they were grouped into two categories of innovativeness: non-innovators (non-adopters) and innovators (adopters). If a farmer fully adopted three innovations, the farmer is regarded as an innovator (adopter) otherwise s/he is a non-innovator (non-adopter). Based on the foregoing, 100 farmers were classified adopters and 170 as non-adopters. This provides a useful basis for empirical analysis of the underlying factors that might contribute to a farmer's innovative capacity or willingness to innovate (adopt).

Table 3.3 Description of variables in the logit model

Variable	**Variable code**	**Description and unit**	***a priori* expectation**
Farm income	INCOME (X_1)	Revenue from farm produce (Naira)	+
Access to information	INFO (X_2)	Visit by extension worker (number of visit)	+
Access to credit	CREDIT (X_3)	Obtained loan to finance farm work (Yes, 1; No, 0)	+/-
Education	LITERACY (X_4)	Level of formal education attained (years)	+
Farming experience	EXP (X_5)	Duration of time engaged in rice farming (years)	+/-
Farm size	SIZE (X_6)	Total land holding owned by the farmer (hectares)	+
Household size	PEOPLE (X_7)	Individuals in a household (number)	+/-
Membership of cooperative society	CLUB (X_8)	Membership of cooperative society (If affiliated = 1, 0 otherwise,	+

A priori expectations of factors influencing of the adoption of modern rice production technologies

Income derived from the farming activities indicates the level of profit of the farmers. The expectation is that farmers will have as much capital to plough back into the production process in order to increase profit. Farmers with good returns from their production activities are more likely to be able to afford and apply expensive inputs aimed at increasing productivity; hence, income is expected to influence innovative behaviour positively.

Access to information is a very important determinant of technology adoption because any newly developed technology is introduced to farmers through the activities of extension agents. A farmer whose contact with extension agents is very high is expected to be more familiar and more knowledgeable about the use of improved agricultural technologies. This variable is expected to have positive effect on innovative behaviour.

Access to credit is expected to assist farmers purchase necessary inputs for crop production. Also, it gives farmers additional resources of investment in new ideas and therefore expected to be positively related to their innovativeness. But if the accesses credit is diverted to uses other than farming, the sign could be negative.

Education is very important for the farmers to understand and interpret the agricultural information coming to them from any direction. A better educated farmer can easily understand and interpret the information transferred to them by extension agent. This variable is expected to affect technology adoption positively.

Farming experience could take positive or negative sign depending on the length of period. It is expected to demonstrate increasing returns up to stage and later diminishing return as more elderly farmers have been reported to be more risk averse, hence, are likely to experiment with new technologies.

Household size is an important socioeconomic characteristic because it often determines how much family labour will be put into use on the farm. The variable is expected to have positive influence on efficiency. If however, the adult ratio is low, the sign could be negative.

Cooperative membership popularizes innovation by making farmers exchange ideas, experiences, and makes it cheaper to source information; knowledge and skills in order to enable them improve their livelihoods. The sign of the parameter of this variable is hypothesized to be positive.

Before using the tobit and logit models, multicollinearity was checked to exclude any highly correlated explanatory variables. With this particular study, there is no serious multicollinearity problem (Appendices 2 and 3). There are various indicators of multicollinearity and no single diagnostic will completely capture collinearity problem. Accordingly, Variance Inflation Factor (VIF) and condition index (CI) were used for continuous variables. If there is larger value of VIF_i, then, multicollinearity is more troublesome. As a rule of thumb, if the VIF of a variable exceeds 10 (this will happen if R^2_iexceeds 0.90), that variable is said to be highly collinear (Gujarati and Porter, 2009). Following Gujarati and Porter (2009), the VIF_j is given as:

$$VIF\ (X_j) = 1/1 - R^2_j \qquad 3.13$$

Where, $R^2_j$is the coefficient of multiple determination when the variable X_j is regressed on the other explanatory variables. There may also be interaction between categorical (dummy) variables, which can lead to the problem of multicollinearity. To detect this problem, Phi (ϕ)coefficients were computed. The Phi (ϕ) coefficient was compounded as follows:

$$\phi = \sqrt{}\chi 2\ /\ n \qquad 3.14$$

Where, ϕ is Phi (ϕ) coefficient

$\chi 2$ is chi-square test and

n = total sample size.

If the value of the Phi coefficient is greater than 0.5, the variable is said to be collinear (Gravetter and Wallnau, 2008).

3.4.4Hypotheses testing

Test of null hypothesis that the farmers are not fully technically and cost efficient was performed using the generalized likelihood ratio test statistic defined by:

$$\lambda = -2\ \{\log\ [L(H_0) - \log[L(H_1)\ ]\ \}, \qquad 3.14$$

where, $L(H_0)$ and $L(H_1)$ denote the values of the likelihood function under the null (H_0) and alternative (H_1) hypotheses, respectively. If the null hypothesis is true, the test statistic has approximately a χ^2 or a mixed χ^2 distribution with degrees of freedom equal to the difference between the parameters involved in the null and alternative hypotheses. The critical values for the generalized likelihood ratio test were obtained from Table 1 of Kodde and Palm (1986). T-test was used to test the second hypothesis; while analysis of variance (ANOVA) and Chi-square tests were used to test the third hypothesis. All the hypotheses of the study were tested at 5% percent level of significance.

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Descriptive statistics of the socioeconomic and production factors

A summary of the values of the production factors and some socioeconomic attributes of the sampled rice farmers is presented in Table 4.1. Adopters of modern rice production technologies obtained higher average yield than their counterparts using the traditional technique. The difference between the adopter categories in terms of yield is substantial as attested by the significance of t-value at 1% level. Similarly, there were significant differences between the adopter categories in terms farm size, hired labour, fertilizer, herbicide, income, education and extension contact. This is confirmed by the significance of these variables at one percent probability level. However, there were no significant differences between adopters and non-adopters in terms of quantities of seed and man-days of family labour used. Whereas the seed rate used by adopters of modern technologies were below the recommended 80 kg/ha (ARC/FAO/SAA, 2008), the non-adopters planted more than the recommended rate. This is due to the fact that most of the non-adopters did not use hybrid seed on which the recommended rate is based, but planted the traditional varieties obtained from the previous year’s harvest. With regards to socioeconomic attributes, there were significant differences in farm income, education and extension contact between the two techniques of rice production at 1% level. Furthermore there were no significant differences between adopters and non-adopters in terms of age, household size and farming experience.

Table 4.1: Summary Statistics of the output, inputs and socio-economic characteristics of the farmers

	Adopters		**Non-adopters**			
	Mean	**Standard deviation**	**Mean**	**Standard deviation**	**T-value**	**p-value**
Paddy output (kg)	2633.50	1537.22	1593.94	837.57	2.59***	0.0000
Farm size(Ha)	1.18	0.55	0.90	0.47	4.93s***	0.0000
Seed (kg)	59.55	35.62	102.15	42.20	-8.47	1.0000
Family labour used (man-days)	46.04	63.50	65.49	6531	-2.39	0.9912
Hired labour used (man-days)	56.96	64.69	25.17	55.82	4.26***	0.0000
Fertilizer used (kg)	149.35	96.73	83.91	47.75	7.42***	0.0000
Herbicide used (litres)	2.98	1.73	1.13	0.88	11.63***	0.0000
Income (₦)	17025.61	10451.61	4960.27	5899.77	12.13***	0.0000
Age (years)	34.62	6.62	51.61	11.73	-13.28	1.0000
Household size (number)	7.65	6.17	14.41	8.36	-7.03	1.0000
Education (years)	7.50	5.59	3.77	4.85	5.76***	0.0000
Extension contact (number)	7.61	2.51	2.35	2.29	17.57***	0.0000
Farming experience (years)	12.6	6.31	12.03	5.86	0.90	0.1838
Total number of observation	100		170			

*** Significant at 1% level, (degree of freedom = 268)
Source: Field survey, 2011

4.2 Maximum Likelihood Estimates, Elasticities and Return to Scale

The maximum likelihood estimates (MLE) of the Cobb-Douglas model of equation 3.1 is presented in Table 4.2. The MLE of the parameters of the stochastic frontier model were obtained using the program FRONTIER 4.1 which also estimates the variance parameters in terms of σ^2 and γ (Coelli, 1996). The variance ratio (γ), defined by equation *3.6*, which was associated with the variance of technical inefficiency effects in the stochastic frontier were about 0.63 and 0.79 for adopters and non-adopters, respectively. This suggests that 63 percent to 79 percent of the total variability of rice output for adopters and non-adopters, respectively, were due to differences in technical efficiency. In other words inefficiency effects as opposed to the random factors are significant in determining the level and variability of rice farmers' output in the study area. Furthermore, it can be said that variation in rice output level across farmers was mainly due to factors within their control and not due to random factors beyond their control like weather and diseases.

The coefficients of the Cobb-Douglas model are important in discussing the results. The land variable (as shown in Table 4.2) was positive and significant ($P < 0.001$) for both the adopters and non-adopters of modern rice production technologies. The positive sign suggests that a unit increase in the variable, when other variables are held fixed would result in increased output of rice. The seed variable was positive and significant under both categories of farmers. The positive sign suggests that other things being equal, the higher the seed rate used the higher the crop population and subsequently high yield except where there is overcrowding leading to competition for available nutrients which will consequently lead to low yield. The variable fertilizer was positive, conform to *a priori* expectation and significant at 1% level for adopters of modern technique of rice production. The significance of the variable derives from the fact that fertilizer is a major land augmenting input in the sense that it improves the productivity of land thus increasing rice yield. The non-significance of the fertilizer variable for the non-adopters could be as a result of low level of use of fertilizer.

The coefficients of the variables of the Cobb-Douglas function represent direct elasticities of response to output for increase in the variables in the model. All the estimated coefficients had elasticities of less than unity implying that one percent increase in any of the variables holding others fixed will lead to less than one percent increase in output of rice. The return to scale (RTS) of production obtained as sums of the elasticities of production were 0.95 and 1.19 for adopters and non-adopters, respectively, suggesting decreasing returns to scale for adopters and increasing returns to scale in the non-adopters of modern rice production techniques. The RTS values indicate that rice farmers were operating in stages II and I of production surfaces respectively for adopters and non-adopters, respectively.

Table 4.2: Maximum likelihood estimates of parameters of the Cobb-Douglas Stochastic Production Frontier Function

Variable	Parameter	Adopters		Non-adopters	
Production Factors		***Coefficient***	***t-ratio***	***Coefficient***	***t-ratio***
Constant	β_0	2.249	6.453***	3.309	19.516***
Farm size	β_1	0.101	2.999***	0.758	9.255***
Seed	β_2	0.474	2.973***	0.302	3.599***
Family Labour	β_3	0.022	1.111	0.071	11.238***
Hired Labour	β_4	0.013	1.154	0.028	0.494
Fertilizer	β_5	0.117	2.018***	0.005	0.244
Herbicide	β_6	0.222	2.270***	0.030	0.277
Variance parameter					
Sigma squared	σ^2	0.826	3.406***	0.667	7.487***
Gamma	γ	0.625	2.855**	0.791	8.451***
Log likelihood function		87.316		112.293	
Generalized likelihood ratio		16.621		27.697	
Number of observations		100		170	

*** Significant at 1% ** Significant at 5%

Source: Field survey 2011

The maximum likelihood estimates of the parameters of stochastic cost frontier model are presented in Table 4.3. All parameters estimates except the cost of herbicide had the expected positive signs and significant at 1% level meaning that these factors are significantly different from zero and thus important in rice production. The scale effects among the rice farms in the study area was computed as the inverse coefficient of cost elasticities with respect to the rice output as the only output in the analysis shows that there isscale effects among the sampled farmers. This is affirmed by the value of scale effects (SE) were 3.93 (i.e., 1/0.254) and 21.28 (1/0.0.047). The computed value of the SEs are greater than one, meaning that 1% increase in the total production costs increased the rice production by 3.9% and 21.3% adopters and non-adopters, respectively. The results obtained is an indication that there are positive economies of scales suggesting that an average rice farmer in the sampled area experiences a decrease in total production cost in the course of their production.

Table 4.3: Maximum likelihood estimates of parameters of the Cobb-Douglas Stochastic Cost Frontier Function

Variable	Parameter	Adopters		Non-adopters	
Production factors		***Coefficient***	***t-ratio***	***Coefficient***	***t-ratio***
Constant	β_0	2.065	9.305***	13.916	17.596***
Rent on land	β_1	0.059	1.421	0.226	4.371***
Cost of seed	β_2	0.302	5.998***	0.635	11.938***
cost of family labour	β_3	0.029	6.657***	0.009	4.227***
cost of hired labour	β_4	0.022	5.039***	0.013	10.683***
cost of fertilizer	β_5	0.298	6.213***	0.0005	0.025
cost of herbicide	β_6	0.041	7.032***	-0.003	-1.487
Paddy output	β_7	0.254	5.679***	0.047	5.792***
Variance parameter					
Sigma squared	σ^2	0.441	5.081***	0.586	6.248***
Gamma	γ	0.889	15.466***	0.783	3.420***
Log likelihood function		60.527		122.593	
Generalized likelihood ratio		34.364		48.592	
Number of observations		100		170	

*** Significant at 1%
Source: Field survey 2011

4.3 Analysis of production efficiency

The predicted technical efficiencies of the farmers ranged from 11% to 99% and 14% to 99.7% for adopters and non-adopters, respectively (Table 4.4). The mean technical efficiency was 69.1 and 67.6 respectively for adopters and non-adopters modern rice production techniques. These indicated that the average farmer produced about 69.1% to 67.6% of maximum attainable output for given input levels for adopters and non-adopters, respectively. Although the farmers were relatively efficient, there is still room to increase the efficiency in their rice farming activities. This means that if the average farmer was to achieve the TE level of his or her most efficient counterpart in northeastern Nigeria, he or she would realize 30.2% [i.e. (1 - 69.1/99) x 100] and 32.2% [(1 - 67/99.7) x 100] more productivity for the adopters and non-adopters, respectively. In terms of the distribution of TEs, there appear to be a clustering of the TE levels above 70%, representing 52% and 47% (Table 4.4) of the respondents for the for adopters and non-adopters, respectively.

The predicted allocative efficiencies of the farmers differ substantially between the two categories of farmers. Whereas the mean AE was 66.1% for adopters the value was 30.3% for non-adopters (Table 4.4). This implies that if the average farmers in the sample were to achieve the AE levels of their most efficient counterparts, then the average farmers could realize cost savings of 26.6% [i.e. (1 – 66.1/89.9)] and 60.8% [(1 – 30.3/77.3)] for the adopters and non-adopters, respectively. In terms of the distribution of AE level, while 74% of the respondents attained more than 70% AE level under the adopter category, only 1.2% of the respondent attained the same percentage under the non-adopter category.

The predicted economic efficiencies (EE) estimated as the inverse of cost efficiencies differ significantly among the sampled farmers. The mean EE for adopters and non-adopters were 37.6% and 22.4% respectively. The minimum and maximum values of EE were 4.8% and 84.2%, and 1.8% and 66.1% for adopters and non-adopters, respectively.

The implication of the above findings is that the low production efficiency was as a result of low allocative efficiency. In other words technical efficiency appears to be more significant than allocative efficiency as a source of gain in production efficiency.

Table4.4: Decile range of Technical, Allocative and Economic efficiency levels for the sampled farmers

	Adopters						Non-adopters					
	Technical efficiency		**Allocative efficiency**		**Economic efficiency**		**Technical efficiency**		**Allocative efficiency**		**Economic efficiency**	
Efficiency Level	***Freq.***	***%***	***Freq.***	***%***	***Freq.***	***%***	***Freq.***	***%***	***Freq.***	***%***	***Freq.***	***%***
≤ 10	-	-	-	-	2	2.0	-	-	7	4.1	29	17.1
11 – 20	1	1.0	4	4.0	12	12.0	2	1.2	29	17.1	58	34.1
21 – 30	3	3.0	6	6.0	8	8.0	2	1.2	42	24.7	56	32.9
31 – 40	2	2.0	2	2.0	10	10.0	10	5.9	64	37.6	20	11.8
41 – 50	10	10.0	6	6.0	25	25.0	25	14.7	19	11.2	5	2.9
51 – 60	13	13.0	8	8.0	23	23.0	27	15.9	6	3.5	1	0.6
61 – 70	19	19.0	19	19.0	14	14.0	24	14.1	1	0.6	1	0.6
71 – 80	26	26.0	27	27.0	4	4.0	31	18.2	2	1.2	-	-
81 – 90	14	14.0	28	28.0	2	2.0	22	12.9	-	-	-	-
≥ 91	12	12.0	-	-	-	-	27	15.9	-	-	-	-
TOTAL	100	100	100	100	100	100	170	100	170	100	170	100
Minimum	11.0		10.1		4.8		14.0		3.1		1.8	
Maximum	99.0		89.9		84.2		99.7		77.3		66.1	
Mean	69.1		66.1		37.6		67.6		30.3		22.4	

Source: Field survey 2011

4.4 Determinants of efficiency

The parameters of the two-limit Tobit model are presented in Table 4.5. A total of seven (7) variables were included in the model. Out of these, all except age and membership of association significantly affect farmers' efficiency.

The variable, family size, defined by number of persons in a household was found to have a negative but significant relationship with AE and EE (Table 4.5). This is consistent with the findings of Mbanasor and Kalu (2008). The implication of this result is that availability of farm labour which to some extent depends on household size could influence efficiency. The negative coefficient could be as a result of shortage of labour.

Extension contact had positive and significant ($P<0.001$) correlations with AE and EE, while the coefficient of this variable in TE is negative and statistically not significant. This result is partly consistent with findings of Bravo-Ureta and Pinheiro (1997). The negative coefficient of TE could be as a result of low visit by extension agents which results in adequate guidance on production recommendations. The positive and significant value of AE could be that the extension agents were at least able to provide valuable information about where the farmers could afford to purchase quality inputs.

Education is an important determinant of farm-level efficiency. Well educated farmers tend to exhibit higher levels of efficiency. The variable was found to be positively related to AE and EE but significant only on AE. This is consistent with the findings of Laha and Kuri (2011) who reported positive and significant relationship between education and AE among farm households in West Bengal, India. The implication of this finding is that with increased level of educational attainment, farmers' skills of decision making in the use of inputs for increased efficiency and productivity could be enhanced.

Credit was specified as a binary variable. Of the variables in the second step analysis, credit is the only variable that has the same negative sign and is statistically significant in TE, AE and EE at 1%, 10% and 1% levels, respectively. The result is contrary to findings of Bravo-Ureta and Evenson (1994) who reported positive and significant relationship between credit and efficiency among peasant farmers in eastern Paraguay. The significance of the variable suggests its importance for good performance by affording the farmers the purchasing power to procure inputs needed for rice production. The negative sign could be as a result of little access to the incentive orchestrated by the cumbersome nature of the loan processing procedure and/or high transactional cost of borrowing, most especially from the formal sources.

The coefficients of systems of land ownership were negative for all the efficiency (TE, AE and EE) but statistically significant for AE and EE at 10% and 5% respectively. The negative coefficient may not be unconnected with the fact that only a few of the farmers owned their farmlands as opposed to the majority who obtained their land through rent. Ownership through the latter has negative effects on specialization and consequently leads to decreased efficiency.

Table 4.5: Two-limit equation of factors that influence technical (TE), allocative (AE) and economic efficiency (EE) efficiency of the sampled farmers

Variable	**Para-meter**	**Technical**		**Allocative**		**Economic**	
Production Factors		***Coeffi-cient***	***t-ratio***	***Coeffi-Cient***	***t-ratio***	***Coeffi-cient***	***t-ratio***
Constant	ω_0	0.6301	3.56***	0.7074	3.76***	0.4813	3.18***
AGE	ω_1	0.0316	0.28	-0.858	-0.70	-0.0658	-0.67
PEO	ω_2	-0.0444	-1.17	-0.1554	-3.85***	-0.1099	-3.39***
EDU	ω_3	-0.0040	-0.62	0.0135	1.96*	0.0069	1.25
EXT	ω_4	-0.0088	-1.16	0.0369	4.56***	0.0222	3.42***
ASSO	ω_5	0.0014	0.15	-0.0014	-0.13	-0.0040	-0.47
CREDIT	ω_6	-0.0245	-2.87***	-0.0164	-1.81*	-0.0194	-2.67***
TEN	ω_7	-0.0137	-1.54	-0.0184	-1.95*	-0.0160	-2.11**
Log likelihood function		64.16		47.70		106.63	
Chi-squared		12.43*		79.88***		59.98***	

*** Significant at 1% ** Significant at 5% * Significant at 10%
Source: Source: Field survey 2011

4.5 Factors influencing the adoption of modern rice production technology

Explanatory variables that were selected for econometric model were discussed based upon the model output. Accordingly, as indicated in Table 4.6, about 96 % of the total variation for the modern rice production technique is explained by logistic model. The $\chi 2$ result which is significant ($P<0.001$) shows that the model fits the data. The model correctly predicted sample size of 95 % and 96.5% for adopters and non-adopters, respectively.

All the variables included in the model had the hypothesized signs. The decision by households to adopt modern rice technologies significantly is influenced by income ($p<0.001$), access to information ($p<0.001$), access to credit ($p<0.001$), level of education of the household head ($p<0.05$), household size ($p<0.05$) and membership of cooperative society ($p<0.01$).

Table 4.6: Logit equation of factors influencing the adoption of modern rice production technologies offarmers

Variables	Coefficients (B)	Standard error	Wald	Significance	Exp (B)
Constant	-3.704	1.673	4.902	0.027**	0.025
INCOME	0.0003	0.000	20.334	0.000***	2.522
INFO	0.816	0.171	22.778	0.000***	2.261
CREDIT	-3.885	0.877	19.636	0.000***	0.021
LITERACY	0.181	0.079	5.211	0.022**	1.199
EXP	-0.009	0.055	0.024	0.878	0.992
SIZE	0.141	0.744	0.036	0.849	1.152
PEOPLE	-0.253	0.112	5.108	0.024**	0.776
CLUB	2.191	0.849	6.656	0.010***	1.112
Number of farmers	270				

Source: Source: Field survey 2011

*** Significant at 1% ** Significant at 5%

-2 log likelihood	61.548	
Chi-square ($\chi 2$)	294.359***	
Predicted	Adopter	95%
	Non-adopter	96.5%
	Overall	95.9%

The odds ratio [Exp(B)] for this variable was 2.261 (Table 4.6), which suggest that farmers who had more contact with extension agents are more than two times likely to adopt modern rice technologies than those with no access to extension agents.

Income derived from the farming activities indicates the level of profit of the farmers. The expectation is that farmers will have as much capital to plough back into the production process in order to increase profit. The results in Table 4.6 indicate that income was positive and significant ($P<0.001$). The implication of this finding is that farmers with good returns from their production activities are more likely to be able to afford and apply expensive inputs aimed at increasing productivity.

The results in Table 4.6 revealed that access to information defined by number of visits by the extension agents to farmers significantly ($P<0.001$) affects adoption of modern rice production technologies. The positive and significant coefficient of access to information could be attributed mainly to the fact that knowledge gained from the contacts with extension agents by the farmers' influence them to adopt new technologies. This is in consonance with the findings of Tiamiyu *et al.* (2009) who reported a positive relationship between extension visits and technology adoption among growers of New Rice for Africa (NERICA) in savanna zone of Nigeria.

The coefficient of access to credit had the hypothesized positive sign and significant ($P<0.001$). The significance of the variable stemmed from the fact that agricultural credit is a basic tool of production which provides farmers with additional source of investment in modern production technologies. The more access farmers have to credit facilities the higher the likelihood that they may adopt modern technologies recommended to them. The positive effect of the variable on adoption is a reflection of ability to purchase productive inputs for farming activities. This concurred with studies by Foti *et al*. (2008) who reported a positive relationship between farm size (taken as a surrogate for wealth and access to credit) and the adoption of selected soil fertility and water management technologies in semi-arid Zimbabwe.

Literacy level had a positive coefficient and significant at 5% level. This conformed to *a priori* expectation. This is in consonance with the findings of Lawal *et al.* (2004) who reported positive and significant relationship between education and adoption of improved maize varieties among smallholder farmers in southwestern Nigeria. This shows that being literate farmers easily understand and analyze the situation better than illiterate farmers. Another explanation could be, the more years of formal schooling farmers had, the better enlightened they become and subsequently the easier it becomes for them to better understand and adopt production recommendations.

As shown in Table 4.6, the coefficient of family size, which is defined by the number of people in a household had negative coefficient and statistically significant at 5% level. The negative coefficient of family size could be as a result of low adult ratio in the sampled households. The significance of the variable could be explained by the fact that labour is an important input in rice production.

Membership of cooperative society had positive and significant ($p<0.05$) influence on adoption behaviour of the sampled farmers. The result is in agreement with that reported by Mihiretu (2008). Adoption of modern rice technologies could be motivated by belonging to a cooperative society. Cooperative membership popularizes innovation by making farmers exchange ideas, experiences; and makes it cheaper to source information, knowledge, and skills in order to enable them improve their livelihoods.

4.6 Problems faced by rice farmers in north-eastern Nigeria

Results in Table 4.7 indicate that the most serious constraints faced by the rice farmers were inaccessibility to cheap farm inputs, inadequate rainfall, conflicts with grazing nomads, inadequate credit facilities and birds' invasion. Some of the problems as pronounced by the farmers are presented below:

a) Inaccessibility to cheap farm inputs

High costs of important farm inputs such as improved seeds, fertilizer and pesticides militates against effective performance of the farmers. 96.3% of the farmers opined this constraint. They identified the problem of fertilizer as largely its inaccessibility as such they cannot afford to purchase the right quantities when needed for increased productivity. They further complained that even if they were available, middlemen hijacked the commodity and sell to them in the open markets at exorbitant prices.

b) Inadequate rainfall

Water is an essential natural resource needed for rice production. Shortage of this resource could spell doom for any rain-fed rice producer. Given that the study area is located in the northern guinea savannah, there is likelihood that shortage of rainfall could be experienced. About 91% of the farmers complained of shortage of rain as a serious problem to them.

c) Inadequate credit facilities

Inadequate access to credit facilities militates against efficient rice cultivation in the study area. About 82.5% of the sampled farmers claimed this constraint. They complained that most of the times individuals not engaged in farming benefits from loans at the expense of the genuine farmers. The implication of this was that farmers who would have benefited from the credit facilities did not, hence, the under-utilization of some inputs with resultant low productivity.

d) Birds' invasion

High Quelea birds' invasion of farmers' field posed serious threats to their production activities. About 78% of sampled farmers opined this problem. This problem is further complicated especially in Lamurde and Lau local government areas by the sugarcane plantation that provides roosting place for the birds. In some of the areas, the invasion by the birds was as a result of delayed planting and/or planting of late maturing varieties.

e) Inadequate extension support

Farmers need to harness, coordinate and utilize efficiently the resources at their disposal and to do so they need guidance. Well-coordinated extension programme delivered through highly skilled and dedicated extension agents is a vital tool in persuading farmers to change from their traditional farming techniques to modern one which result in increased efficiency. However, extension support was not adequate. Result in Table 4.7 showed that more than 70% of the farmers claimed this problem. This they further stated is complicated by the infrequent visits by the extension agents.

Table4.7: Problems faced by rice farmers in Northeastern Nigeria

Problems	No of farmers	Percentage*	Rank
a) Birds invasion	210	77.78	5
b) Inaccessibility to cheap farm inputs	260	96.30	1
c) Inadequate extension support	200	74.07	6
d) Inadequate credit facilities	220	82.48	4
e) inadequate rainfall	245	90.74	2
f) Low paddy prices	102	37.78	7
g) land tenure problems	80	29.62	8
h) Conflict with grazing nomads	240	88.89	3

*Multiple responses
Source: Field survey 2011

4.7 Test of hypotheses

Hypothesis 1: Rice producers in the study area are fully technically and cost efficient.

The result of the test of hypotheses that farmers are fully technically and cost efficient is presented in Table 4.8. The null hypotheses specify that that the technical inefficiency effects in the stochastic frontier production are not stochastic. This null hypothesis is rejected for both techniques. This rejection of the null hypothesis indicates that the rice farmers are not fully technical and cost efficient.

Table 4.8 Generalized likelihood ratio test

Null hypothesis*	Likelihood function	λ	χ^2- Critical (0.05)†	Decision
Modern: Ho: $\gamma_1 = 0$	87.316	16.621	2.706	Reject Ho
Traditional: Ho: $\gamma_1 = 0$	112.293	27.697	2.706	Reject Ho
Modern: Ho: $\gamma_2 = 0$	60.527	34.364	2.706	Reject Ho
Traditional: Ho: $\gamma_2 = 0$	122.593	48.592	2.706	Reject Ho

*Subscripts 1 and 2 refers to production and cost frontiers respectively

†This value is obtained from Table 1 of Kodde and Palm (1986) which give critical values for test of null hypothesis involving parameters having values in boundary of the parameter space at 5% level and degree of freedom equal to number of restrictions, which one (1).

Hypothesis 2: There is no difference in mean efficiency of farmers using modern technologies and those using traditional technology.

The results of the t-test of differences between mean efficiency of the rice production techniques is presented in Table 4.9.It indicates that significant differences exist between the mean efficiency of farmers using the two rice production technologies in the study area.

Table 4.9: T-tests of difference between mean efficiency of rice farmers

Null hypothesis	Computed t-value	Degree of freedom	p-value	decision
Ho: $EE_1 = EE_2$	14.12	268	0.0000	Reject Ho

Subscripts 1 and 2 refers to modern and traditional production techniques respectively

Hypothesis 3: Socioeconomic and institutional factors have no influence on farmers' innovative behaviour.

Farm Income

Farm income is the main source of capital to purchase farm inputs and other household consumable goods. It refers to the total annual earning of the family from the sale of paddy rice harvested after meeting family requirements. As portrayed from Table 4.10, the average annual farm income of the sampled household was ₦ 9428.91, whereas that of adopters was ₦ 17025.61 and that of non-adopters was ₦4960.27. One way ANOVA analysis was run to check whether there is a significant mean difference in mean annual farm income between adopters and non-adopters. The result of F-test showed that there was significant mean difference (F=147.12, P=0.000) among adoption categories implying the presence of significant relationship (Table 4.10). The finding conforms to that of Mihiretu (2008) who reported significant relationship between annual farm income and adoption behaviour of onion farmers in Fogera district, South Gondar, Ethiopia.

Table 4.10:ANOVA of the influence of farm income on adoption behaviour of farmers

Category	Frequency	Mean	Standard deviation	F-value	P-value
Adopter	100	17025.61	10451.61		
Non-adopter	170	4960.27	5899.77		
Total	270	9428.91	9805.26	147.12**	0.0000

***Significant at 5% level
Source: Field survey, 2011

Access to information

The major sources of agricultural information for farmers are extension agents. It is hypothesized that frequency and timely contact with extension workers will increase a farmer's probability of adopting technologies. The relationship between extension contacts and adoption of modern rice production was found to be significant as shown in Table 4.11. From the total sample households, 27.4% were reported not having contact with extension agent, while 72.6% of sample households were reported having contact with the extension agent at different level of frequency. From the non-adopter groups, 43.5% of respondent did not have any contact with extension agents. The percentage of respondents not having contact with extension agent, all comes from the non-adopters as compared to the respondents of adopter category. The chi-square analysis result ($\chi2 = 59.96$, $p = 0.000$) shows significant relationship of contact of extension agent with the adoption of rice production package. This result is similar to those reported by Abrhaley (2007), Girmachew (2005) and Kidane (2001).

Table 4.11: Chi-square of the relationship between extension contact and adoption behaviour of farmers

	Status of visit				
Category	Visited	Not visited	Total	χ^2	p- value
Adopter	100	0	100		
Non-adopter	96	74	170		
Total	196	74	270	59.96**	0.000

***Significant at 5% level
Source: Field survey, 2011

Access to credit

Adoption of modern rice production technologies by farmers is motivated by the income gained from the sale of the produce. Farmers produce rice not only for consumption purpose but to fetch cash income which is allocated for purchasing farm inputs and meet up other family needs. Without cash and access to credit, farmers will find it very difficult to adopt new technologies. It is expected that access to credit will increase the probability of adopting modern rice production technologies. This preposition is hypothesized by many authors. In this study too, this hypothesized preposition is supported by the significant relationships which exist between access to credit and adoption of modern rice production technologies ($\chi2$ = 121.503, P = 0.000) as shown in Table 4.12. This relationship is also reflected in distribution of percentage of respondents where 16.5% of non- adopters had access to credit.

Table 4.12: Chi-square of the relationship between access to credit adoption behaviour of farmers

	Credit status				
Category	**access**	**No access**	**Total**	**χ^2**	**p- value**
Adopter	85	15	100		
Non-adopter	28	142	170		
Total	113	157	270	121.50**	0.000

***Significant at 5% level
Source: Field survey, 2011

Educational status of Sample household heads

Education is very important for the farmers to understand and interpret the agricultural information coming to them from any direction. A better educated farmer can easily understand and interpret the information transferred to them by extension agent. As indicated in Table 4.13 from among the sample households, 43.33% were illiterates and 56.67% were literates. In this study the literacy means completing primary school education. To see the relationship and the intensity of relationship, the chi-square- test was conducted. The result of chi-square- test ($\chi2$=29.44, P=0.000) revealed that there is significant difference between education and the adoption of modern rice production technologies. The result of this study is in agreement with the studies conducted by Taha (2007) reported significant relationship of education with the adoption of improved onion production package. Similarly Addis (2007) and Mahdi (2005) reported positive and significant relationship of education with the adoption of technology.

Table 4.13: Chi-square of the relationship between educational status and adoption behaviour of farmers

	Literacy status				
Category	**Illiterate**	**Literate**	**Total**	**χ^2**	**p- value**
Adopter	22	78	100		
Non-adopter	95	75	170		
Total	117	153	270	29.44**	0.000

***Significant at 5% level
Source: Field survey, 2011

Farm size

Land is the main asset of farmers in the study area. Farmers in the study area use both their own land and also rent farm land for rice production. The average farm of the sample households were 1.34 hectare. The minimum and maximum total land holding of the respondents ranges from 0.1 to 3 hectares. The total average land used for improved rice crop production by respondents was 0.39 hectare. The average total land holding of the non-adopters group was 0.90 ha whereas the adopter category was 1.22 ha. One way analysis of variance (F=26.34, p=0.000) statistical analysis revealed mean difference statistically among adoption categories at less than 1 % level (Table 4.14). The result of this study is in harmony of the past findings of Mulugeta *et al.*, 2001; Yishak, 2005 and Mesfin, 2005.

Table 4.14:ANOVA of the influence of farm size on adoption behaviour of farmers

Category	**Frequency**	**Mean**	**Standard deviation**	**F-value**	**p-value**
Adopter	100	1.18	0.55		
Non-adopter	170	0.93	0.47		
Total	270	1.02	0.52	26.34**	0.0000

***Significant at 5% level
Source: Field survey, 2011

Family size

Family size in the study is considered as the number of individuals who resides in the respondent's household. Large family size assumed as an indicator of labour availability in the family. Based on this fact this variable was hypothesized to have positive and significant relationship with adoption of modern rice production techniques. As shown in Table 4.15, the average family size of the respondents was 11.23 members. The minimum family size of the sample households was 1 for both production systems while the maximum were 25 and 45 persons for the adopters and non-adopters respectively. The results show that there is significant mean difference among the adopter categories (F= 89.31, p=0.000). This significance of the variable could be as a result of high adult ratios in the families.

Table 4.15:ANOVA of the influence of family size on adoption behaviour of farmers

Category	Frequency	Mean	Standard deviation	F-value	p-value
Adopter	100	5.62	4.85		
Non-adopter	170	14.52	8.65		
Total	270	11.23	8.62	89.31**	0.0000

***Significant at 5% level
Source: Field survey, 2011

Membership of cooperative society

Cooperatives serve as an important source of rural credit and input supply. A farmer who is member of service cooperative has more chance to get credit. Therefore, the membership in cooperative was hypothesized to have positive and significant relationship with adoption of modern rice production technologies. As was expected, the membership of cooperative society had significant relationship (χ2=50.78, p=0.000) with the adoption modern rice production technologies at 1% level of significance (Table 4.16). The majority (about 56%) of total sample households were found to be affiliated to cooperative societies and the rest 44.07% were reported to be non-members. Whereas 84% of the adopters were members of cooperative societies, only 39.41% of the non-adopters were the member of cooperative society. The significant relationship between member of a cooperative society and adoption is an indication for the importance of financial institutions in supporting agricultural production. Cooperative members were found to be better in access to and use of credit services.

Table 4.16: Chi-square of the relationship between membership of cooperative society and adopter behaviour of farmers

	Literacy status				
Category	**Affiliated**	**Not affiliated**	**Total**	**χ^2**	**p- value**
Adopter	84	16	100		
Non-adopter	67	103	170		
Total	151	119	270	50.78**	0.000

**Significant at 5% level
Source: Field survey, 2011

CHAPTER FIVE
SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

This study was designed to empirically investigate production efficiency differentials and adoption (innovative) behaviour among rice producers in North-Eastern Nigeria. Specifically, the study sought to analyze the socioeconomic and production factors of the rice farmers in the region; measure technical, allocative and economic efficiencies of the farmers under traditional and modern production technologies; identify the determinants of technical, allocative and economic efficiencies associated rice production in the region; identify factors that influence the adoption of modern production technologies by the rice farmers; and identify constraints associated with rice production in the study area.

Data for the study was collected from a sample of 270 rice farmers whose responses were sought on their production activities. Descriptive statistics, Stochastic Frontier Production and Cost Functions, Tobit regression and Logistic regression were used in analyzing the data.

Results revealed that adopters of modern rice production technologies obtained higher average yield than the non-adopters. The difference between the two adopter categories in terms of yield is substantial as indicated by the significance of t-value at 1% level. However, there were no significant differences between the adopter and non- adopters in terms of quantities of seed and man-days of family labour used. Whereas the seed rate (50.5 kg/ha) used by adopters of modern rice technologies were below the recommended 80 kg/ha, the non-adopters planted more than the recommended rate (113.1 kg/ha). The mean technical efficiency was 0.691 and 0.676, respectively, for adopters and non-adopters indicating that the average farmers, respectively, produced about 69.1% to 67.6% of maximum attainable output for given input levels. Although the farmers were relatively efficient, there is still room to increase the efficiency in their rice farming activities. If the average farmer was to achieve the TE level of his or her most efficient counterpart in northeastern Nigeria, he or she would realize 30.2% and 32.2% more productivity for the adopter and non-adopter categories, respectively. In terms of the distribution of TEs, there appear to be a clustering of the TE levels above 70%, representing 52% and 47% of the respondents for the adopters and non-adopters, respectively.

The predicted allocative efficiencies of the farmers differ substantially between the two adopter categories. Whereas the mean AE was 66.1% in the adopter category, the value was 30.3% in the non-adopter suggesting that if the average farmers in the sample were to achieve the AE levels of their most efficient counterparts, then the average farmers could realize cost savings of 26.6% and 60.8% for the adopter and non-adopter categories, respectively. In terms of the distribution of AE level, while more than 50% of the respondents attained more than 70% AE level under the adopters' category, only 1.2% of the respondent attained the same percentage under the non-adopters' category. The mean EE for adopters and adopters were 37.6% and 22.4%, respectively. The minimum and maximum values of EE were 4.8% and 84.2%, and 1.8% and 66.1% for adopters and non-adopters respectively.

Family size, education, extension contact, access to credit and system of land ownership significantly influence production efficiency of the farmers. Furthermore, farm income, access to information, access to credit, education level of household head, family size and membership of cooperative society were found to have played significant role in the adoption of modern rice farming technique. Respondents indicated inaccessibility to cheap farm inputs (96.3%), inadequate rainfall (90.7%), conflict with grazing nomads 88.9% and inadequate credit facilities (82.5%) as some of the major problems affecting their production activities. It is therefore concluded that there exist differences in allocative and economic efficiency among rice farmers in the study area. It is recommended that farm inputs should be made available by the government at the right time and quantities and at affordable prices. Additionally, farmers should organize themselves into viable cooperative groups to take advantage of economies of scale in bulk purchase of inputs at subsidized rates

5.2 Conclusion

This study concluded that there is substantial difference in the levels of production inefficiencies among the sampled rice farmers. Access to information, literacy level and membership of cooperative society played leading roles in influencing the adoption behaviour of the farmers. Hence, policies that will affect these variables should be vigorously pursued if Nigeria is to achieve self-sufficiency in rice production.

5.3 Recommendations

From the findings of this study, it is obvious that a lot of factors constrained increased rice production. To address these constraints and subsequently increase farmers' productivity and efficiency, the following recommendations are proffered.

i. From the study, it is observed that resource adjustment is paramount for increased productivity. The inefficiency in the use of some of these resources was as a result of inaccessibility and/or unavailability. Therefore, farm inputs should be made available by the government at the right time and quantities and at affordable prices. Since farmers are price responsive in the use of these inputs, government should endeavor to remove all distributional bottlenecks which affect the availability and prices at the grass root level of these inputs especially fertilizer and agro-chemicals.

ii. Inadequate rainfall is the second most serious constraint reported by the sampled farmers. This problem could be as a result of their failure to engage in early planting and/or planting early maturing varieties in order to escape from early cessation of rains. To overcome this constraint, rice farmers should endeavour to plant as early as possible once the rainy season sets in and/or plant early maturing rice varieties.

iii. Conflict with grazing nomads is one of the problems militating against the performance of the sampled farmers. The problem might have arisen from the farmers cultivating on designated cattle routes and/or involved in late harvest. The farmers should try to refrain from farming on designated cattle roots as well as harvest their crops as soon as they are ready for harvesting. Also, government should ensure that grazing reserves are established and the Fulani herdsmen should be encouraged to restrict their herding activities within those reserves.

iv. Government support in terms of revitalization and priority funding of the extension delivery activities of the states' agricultural development programmes (ADPs) is required. This will help to mobilize the extension workers to reach the farmers with relevant information on improved farm management practices. Monitoring and evaluating the extension agents should also be intensified to ensure efficient dedication to duty.

5.4 Suggestions for further research

This research is limited to only one of the six agricultural zones of the country. Similar research should be conducted in all agricultural zones of Nigeria to better assess the efficiency of resource use among rice farmers in the country. Also, static model to adoption studies using cross sectional data was employed in this research. Adoption decision is a dynamic process involving changes in farmers' perceptions and attitudes as acquisition of better information progresses and farmers' ability and skill improve in applying new methods. Therefore, there is need to know which rice technologies have been adopted and why they are still in use or already abandoned after introduction. This kind of study will require the application dynamic models using panel data.

5.5 Contributions of the study to knowledge

The findings of this research questioned the validity of the "efficiency hypothesis" which stated that peasant farmers are poor but efficient since the environment in which the farmers operate is no longer static but characterized by changes in technology and economy. Also, the research established that it will be worthless to enhance agricultural performance through promoting the use of improved production technologies alone without equally promoting the capacity of the users of the improved technologies.

REFERENCES

Abrhaley G.(2007). Farmers' Perception and Adoption of Integrated Striga Management Technology in Tahtay Adiabo Woreda, Tigray, Ethiopia, unpublished M.Sc. Thesis Submitted to School of Graduate Studies, Haramaya University, Ethiopia.

Addis A. (2007). Dairy Extension and Adoption of Dairy Package in Fogera Woreda of the Amhara Regional State, M.Sc. Thesis (Unpublished) Submitted to School of Graduate Studies, Haramaya University, Ethiopia.

Adegboye, R. O. (2004). Land, Agriculture and Food Security in Nigeria, 3rd Faculty Lecture, Faculty of Agriculture, University of Ilorin, 25th February.

Adeoti, A. I. and O. I. Ogwudike (2003). Determinants of Household Food Security among Urban Farmers, *ASSET Series A*, 3(3): 99-105.

Afriat, S. N. (1972). Efficiency Estimation of Production Functions, *International Economic Review*, 13: 568-598.

Africa Rice Centre, ARC (2007). 2007 *Africa Rice Trends*, 5th Edition, WARDA, Cotonou, Benin.

Agada, J. E. and D. Philip (2002). A Logit Analysis of the Participation in the Nigerian Agricultural Insurance Scheme by Maize Growing Farmers in Kaduna State, *ASSET Series A*, 2(1): 157-163.

Agada, J. E., D. O. A. Philip and R. S. Musa (1997). A Logit Model for Evaluating Poultry Farmers Participation in Agricultural Insurance Scheme in Kaduna State, Nigeria, *Nigerian Journal of Rural Economic and Society* 1(3): 49-55.

Aigner, D. J. and S. F. Chu (1968). On Estimating the Industry Production Function, *American Economic Review*, 58: 826-839.

Aigner, D., C. A. K. Lovell, and P. Schmidt (1977). Formulation and Estimation of Stochastic Frontier Production Function Models, *Journal of Econometrics*,6: 21-37.

Ajibefun, I. A. and E. Aderinola (2003). Determinants of Technical Efficiency and Policy Implications in Traditional Agricultural Production: Empirical Study of Nigerian Food Crop Farmers, Work-in-process Report Presented at the Biennial Research Workshop of AERC, Nairobi Kenya, May 24th-29th.

Akande, T. (2001). An Overview of the Nigerian Rice Economy, A Project Report, The Nigeria Rice Economy in a Competitive World: Constraints, Opportunities and Strategic Choices, WARDA, 11p.

Akpokodje, G., F. Lancon and O. Erenstein (2001). Nigeria's Rice Economy: State of the Art, A Project Report, The Nigeria Rice Economy in a Competitive World: Constraints, Opportunities and Strategic Choices, WARDA, 55p.

Alamu, J. F. and U. M. Aminu (2003). Socio-Economic Factors influencing Participation in Crop Insurance by Rice Farmers in Kano State, Nigeria, *ASSET Series A*, 3(3): 7-15.

Alene, A. D. (2003). Improved Production Technology and Efficiency of Smallholder Farmers in Ethiopia: Extended Parametric and Non-Parametric Approaches to Production Efficiency Analysis, Unpublished Ph.D Thesis submitted to the Department of Agricultural Economics, Extension and Rural Development, University of Pretoria, South Africa.

Ali, M and M. A. Chaudhry (1990). Inter-regional Farm Efficiency in Pakistan's Punjab: A Frontier Production Function Study, *Journal of Agricultural Economics*, 41: 62-74.

Ali, M. and D. Byerlee (1991). Economic Efficiency of Small Farmers in a Changing World: A Survey of Recent Evidence, *Journal of International Development*, 3(1): 1-27.

Ali, M. and J. C. Flinn (1989). Profit Efficiency among Basmati Rice Producers in Pakistan Punjab, *American Journal of Agricultural Economics*, 71: 303-310.

Amaza, P. S. and A. K. Tashikalma (2003). Technical Efficiency of Groundnuts Production in Adamawa State, Nigeria, *Journal of Arid Agriculture,*13: 127 – 31.

Amaza, P. S. and D. C. Maurice (2005). Identification of Factors that influence Technical Efficiency in Rice-Based Production Systems in Nigeria, Paper Presented at Workshop on Policies and Strategies for Promoting Rice Production and Food security in Sub-Saharan Africa, Cotonou, Benin Republic, November 7th – 9th.

Amaza, P. S. and J. K. Olayemi (2002). Analysis of Technical Inefficiency in Food Crop Production in Gombe State, Nigeria, *Empirical Economic Letters*, 9:51-54.

Amos, T. T., D. O. Chikwendu and J. N. Nmadu (2004). Productivity, Technical Efficiency and Cropping Patterns in the Savanna Zone of Nigeria, *Journal of Food, Agriculture and Environment*2: 173-176.

ARC/FAO/SAA (2008). NERICA: the New Rice for Africa – A Compendium. E. A. Somado, R. G. Guei and S. O. Keya (eds.). Cotonou, Benin: Africa Rice Center (WARDA); Rome, Italy: FAO; Tokyo, Japan: Sasakawa Africa Association. 210 pp.

Arene, C. J. (1992). Rice Production and Factor Productivity in Nigeria, *Journal of Productivity*, 33 (1): 85-88.

Arene, C. J. (1995). Measurement of Resource Productivity and the Efficiency of Labour-Use among Smallholder Rice Farmers in Nigeria, *Modelling, Measurement and Control*, 12 (2): 1-13.

Asfaw N., K. Gungal, W. Mwangi and S. Beyene (1997). Factors Affecting Adoption of Maize Production Technologies in Ethiopia. *Ethiopian Journal of Agricultural Economics.* 2: 52-69.

Assefa, A. (1995). Analysis of Production Efficiency and the Use of Modern Technology in Crop Production: A Study of Smallholders in the Central Highlands of Ethiopia, Abeiten Zur Agrarwirshaft in Entwicklungsländern, Kiel: Wissenschaftsverlag Vauk.

Babatunde, R. and E. Oyatoye (2004). Food Security and Marketing Problems in Nigeria: The Case of Maize Marketing in Kwara State, University of Hohenheim D-70593 Stuttgart, Germany.

Bagi, F. S. (1982). Relationship between Farm Size and Technical Efficiency in West Tennessee Agriculture, *Southern Journal of Applied Economics*, 14: 139-144.

Bamire, A. S., A. O. Adejobi, A. A. Akinola and O. Olagbaju (2007). Socio-economic Factors influencing the Choice of Soil Amendment Techniques among Maize Farmers in Oyo State, Nigeria, *In* Haruna U, Jibril S. A., Mancha Y. P and Nasiru M. (eds), *Consolidation of the Growth and Development of Agricultural Sector*, Proceedings of the 9th Annual Conference of Nigerian Association of Agricultural Economists held in Bauchi, from 5th to 8th November, Pp 433-441.

Banker, R. D., A. Charnes and W. W. Cooper (1984). Some Methods of Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis, *Management Sciences*, 30: 1078-1092.

Battese, G. E. (1992). Frontier Production Functions and Technical Efficiency: A Survey of Empirical Applications in Agricultural Economics, *Agricultural Economics*, 7: 185-208.

Battese, G. E. and G. S. Corra (1977). Estimation of a Production Frontier Model: With Application to the Pastoral Zone of Eastern Australia, *Australian Journal of Agricultural Economics*,21: 167-179.

Battese, G. E. and T. J. Coelli (1988). Prediction of Farm-Level Technical Efficiencies with a Generalized Frontier Production Function and Panel Data, *Journal of Econometrics*, 38: 387-399.

Battese, G. E. and T. J. Coelli (1995). A Model for Technical Inefficiency Effects in a Stochastic Frontier Function for Panel Data, *Empirical Economics*, 20: 325-332.

Batz, F. J., K. J. Peters and W. Jansen (1999). The Influence of Technology Characteristics on Rate and Speed of Adoption, *Agricultural Economics* 21(2): 121-130.

Berhanu B. (2002). Analysis of Factors Affecting the Adoption of Cross-bred dairy Cowsin Central High lands of Ethiopia. The Case of Degam and Girar Jarso Districts, North Shewa Zone,Ethiopia M.Sc.Thesis (Unpublished) Submitted to School of Graduate Study of Alemaya University, Ethiopia.

Besley, T. and A. Case (1993). Modelling Technology Adoption in developing Countries, *The American Economic Review*, 83(2): 396-402.

Binam, J. N., J. Tonye, and N. Wandji (2005). Sources of Technical Efficiency among Smallholder Maize and Peanut Farmers in the Slash and Burn Agriculture Zone of Cameroon, *Journal of Economic Cooperation*, 26(1): 193-210.

Bravo-Ureta B. E. and A. E. Pinheiro (1997). Technical, Economic and Allocative Efficiency in Peasant Farming: Evidence from The Dominican Republic, *The Developing Economies*, XXXV-1: 48-67.

Bravo-Ureta B. E. and L. Rieger (1991). Dairy Farm Efficiency Measurement using Stochastic Frontiers and Neoclassical Duality, *American Journal of Agricultural Economics*, 73: 421-428.

Bravo-Ureta, B. E. and R. E. Evenson (1994). Efficiency in Agricultural Production: The Case of Peasant Farmers in Eastern Paraguay, *Agricultural Economics*, 10: 27-37.

Byerlee, D. and E. H. dePlanco (1986). Farmers’ Stepwise Adoption of Technological Packages: Evidence from the Mexican Altiplano, *American Journal of Agricultural Economics*, 68(3): 519-527.

Byrnes, D., R. Fare and S. Grosskopf (1984). Measuring Productive Efficiency: An Application to Illinois Strip Mines, *Management Sciences*, 30: 671-681.

Central Bank of Nigeria, CBN (2007). 2006 Annual Report and Statement of Accounts, Central Bank of Nigeria, Abuja.

Charnes, A., W. W. Cooper and E. Rhodes (1978). Measuring the Efficiency of Decision Making Units, *European Journal of Operations Research*, 2: 429-444.

Chayanov, A. A. (1966). On the Theory of Non-Capitalist Economic Systems, In Thorner, D., B. Kerblay and R. Smith (eds), *The Theory of Peasant Economy*, Richard D. Irwin Inc, Homewood, IL.

Chikwendu, D. O. and E. B. Tologbonse (1992). Efficiency of Resource Use in Swamp Rice production among Part-Time and Full-Time Farmers in Bida Area of Niger State, Nigeria, *The Nigerian Journal of Agricultural Extension*, 7(1&2): 30-39.

CIMMYT (1993). The Adoption of Agricultural Technology: A Guide for Survey Design, International Maize and Wheat Improvement Centre, Mexico.

Clay, D. C., V. Kelly, E. Mpyisi and T. Readson (2002). Input Use and Soil Conservation Investments among Farm Households in Rwanda: Patterns and Determinants, *In* Barett, C. B., Place, F. and Ahmed A. A (eds) *Natural Resources Management in African Agriculture*, CABI International, New York.

Coelli, T. J. (1996). *A Guide to FRONTIER Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation*, CEPA Working Paper 96/07, Department of Econometrics, University of New England, Armidale, Australia.

Coelli, T. J., R. D. S. Prasada and G. E. Battese (1998). An Introduction to Efficiency and Productivity Analysis, Kluwer Academic Publications, Boston

Coelli, T. J. and S. Perelman (1999). A Comparison of Parametric and Non-Parametric Distance Functions: With Applications to European Railways, *European Journal of Operations Research*, 117:326-339.

Dasgupta, S. (1989). *Diffusion of Agricultural Innovations in Village India*. WileyEastern Limited, New Delhi. 231p.

Dawang, N. C., S. A. Sanni and B. Ahmed (2007). Factors influencing the Adoption of Local Chicks Multiplication and Production Systems (CMPS) in Plateau State, Nigeria, *In* Haruna U, Jibril S. A., Mancha Y. P and Nasiru M. (eds), *Consolidation of the Growth and Development of Agricultural Sector* Proceedings of the 9th Annual Conference of Nigerian Association of Agricultural Economists held in Bauchi, from 5th to 8th November, Pp 249-254.

Dawson, P. J. and J. Lingard (1989). Measuring Farm Efficiency over Time on Philippine Rice Farms, *Journal of Agricultural Economics*, 40: 168-177.

de Haen, H. and A. Runge-Metzger (1989). Improvements in Efficiency and Sustainability of Traditional Land Use Systems through Learning from Farmers' Practice, *Quarterly Journal of International Agriculture*, 28 (3): 326-350.

Degnet A.(1999). Determinants of Adoption of High Yielding Varieties of Maize in Jimma Zone: The Case of Mana and Kersa Woredas. An M Sc Thesis (unpublished) Submitted to the School of Graduate Studies of Alemaya University, Ethiopia

Debreu, G. (1951). The Coefficient of Resource Utilization, *Econometrica*, 19: 273-292.

Ellis, F. (1988). *Peasant Economics: Farm Households and Agrarian Development*, Cambridge University Press, Cambridge.

Ellis, F. (1993). *Peasant Economics: Farm Household and Agrarian Development*, 2nd Edition, Cambridge University Press, Cambridge.

Ellison, G. and D. Fundenberg (1993). The Rules of Thumb of Social Learning, *Journal of Political Economy*, 101(4): 612-643.

FAOSTAT (2012) Online Database, Accessed 9th January, 2012, http://faostat.fao.org/, Food and Agriculture Organization of the United Nations, Rome.

FAOSTAT (2013) Online Database, Accessed 17th December, 2013, http://faostat.fao.org/, Food and Agriculture Organization of the United Nations, Rome..

Färe, R. S. and C. A. K. Lovell (1978). Measuring the Technical Efficiency of Production, *Journal of Economic Theory*, 19: 150-162.

Färe, R., S. Grosskopf and C. A. K. Lovell (1985). *The Measurement of Efficiency of Production*, Kluwer-Nijhoff Publishing, Boston.

Färe, R., S. Grosskopf and C. A. K. Lovell (1994). *Production Frontiers*, Cambridge University Press, Cambridge.

Farrel, M. J. (1957). The Measurement of Production Efficiency, *Journal of Royal Statistical Society Series A*,120: 253-281.

Feder, G. (1982). Adoption of Interrelated Agricultural Innovations: Complementarity and Impact of Risk, Scale and Credit, *American Journal of Agricultural Economics*, 64(1): 94-101.

Feder, G. and D. Umali (1993). The Adoption of Agricultural Innovations: A Review, *Technological, Forecasting and Social Change*, 43: 215-239.

Feder, G. and G. O'mara (1981). Farm Size and the Diffusion of Green Revolution Technology, *Economic Development and Cultural Change*, 33: 255-298.

Feder, G. and G. O'mara (1982). On Information and Innovation Diffusion: A Bayesian Approach, *American Journal of Agricultural Economics*, 6: 141-145.

Feder, G., R. E. Just and D. Zilberman (1985). Adoption of Agricultural Innovations in Developing Countries: A Survey, *Economic Development and Cultural Change*, 33: 255-298.

Federal Republic of Nigeria, FRN (2007). *Official Gazette, No.24 vol.94*, Federal Government Printer, Lagos, Nigeria.

Food and Agriculture Organization, FAO (2001a). The Economics of Conservation Agriculture, Food and Agriculture Organization of the United Nations, Rome.

Food and Agriculture Organization, FAO (2001b). Economics of Soil Productivity in Sub-Saharan Africa, Food and Agriculture Organization of the United Nations, Rome.

Forsund, F. and E. Jansen (1977). On Estimating Average and Best Practice Homothetic Production Functions via Cost Function, *International Economic Review*, 18: 463-476.

Forsund, F. R. and L. Hajilmarsson (1979). Generalized Farrell's Measures of Efficiency, Swedish Journal of Economics, 70:141-154.

Forsund, F. R., C. A. K. Lovell, P. Schmidt (1980). A Survey of Frontier Production Functions and of their Relationship to Efficiency Measurement, *Journal of Econometrics*, 13: 5-25.

Foti, R., C. Gadzirayi and E. Mutandwa (2008). The Adoption of Selected Soil Fertility and Water Management Technologies in Semi-Arid Zimbabwe: An Application of the Tobit Model , *Journal of Sustainable Development in Africa*, 10(3): 315-330.

Ghatak, S. and K. Ingersent (1984). *Agricultural and Economic Development,* Wheatsheaf Books Ltd, Sussex.

Girmachew, S.(2005). Determinants of Adoption of Soil and Water Conservation Practices in the Environs of Simen Mountains National Park, Ethiopia, M.Sc. Thesis (unpublished) Submitted to School of Graduate Studies of Alemaya University, Ethiopia.

Gravetter, F. J. and L. B. Wallnau (2008). *Essentials of Statistics for the Behavioral Sciences*, 6th Edition, Wadsworth Cengage Learning, pp 492-493

Greene, W. H. (1980). Maximum Likelihood Estimation of Econometric Frontier Functions, *Journal of Econometrics*, 13: 27-56.

Gujarati, D. N. and D. C. Porter (2009). *Basic Econometrics*, McGraw-Hill Book Company, p 340

Habtemariam A.(2004). The Comparative influence of Intervening Variables in the Adoption Behaviour of Maize and Dairy Farmers in Shashemene and Debre Zeit, Ethiopia. Ph. D. Thesis, University of Pretoria, Pretoria.

Hiebert, D. (1974). Risk, Learning and the Adoption of Fertilizer Response Seed Varieties, *American Journal of Agricultural Economics*, 56(4): 764-768.

Jabbar, M. A. and M.Alam, (1993). Adoption of modern rice varieties in Bangladesh. *Bangladesh Journal of Agricultural Economics*, XVI, 2: 77-95.

Jondrow, J., C. A. K. Lovell, I. S. Materov and P. Schmidt (1982). On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Function Model, J*ournal of Econometrics* 19: 233-238.

Just, R. and D. Zilberman (1983). Stochastic Structure, Farm Size and Technology Adoption in Developing Agriculture, *Oxford Economic Papers*, 35(2): 307-328.

Kalirajan, K. (1981). An Econometric Analysis of Yield Variability in Paddy Production, *Canadian Journal of Agricultural Economics*, 29: 283-294.

Kalirajan, K. P and R. T. Shand (1986). Firm and Product Specific Technical Efficiencies and Cycle System, *Journal of Development Studies*, 61: 64-69.

Kalirajan, K. P. (1991). The Importance of Efficient Use in the Adoption of Technology: A Micro-Panel Data Analysis, *Journal of Productivity Analysis*, 2: 113-126.

Kansana, H. S., R.P. Sharma and S. K Sharma (1996). Knowledge and Adoption of Wheat Technology among Contact and Non-contact Farmers. *Agricultural Science Digest*, Karnal.16:154 -156

Kidane G.(2001). Factors Influencing the Adoption of New Wheat and Maize Varieties in Tigray, Ethiopia: The Case of Hawzien Woreda, unpublished M.Sc. Thesis presented to School of Graduate Studies of Alemaya University, Ethiopia.

Kislev, Y. and N. Schchori-Bachrach (1973). The Process of Innovation Cycle, *American Journal of Agricultural Economics*, 55(1): 28-37.

Knox, A., R. Meinzen-Dick and P. Hazell (1998). Property Rights, Collective Action and Technologies for Natural Resource Management, IFPRI, Washington, D.C.

Kodde, D. A. and F. C. Palm (1986). Wald Crateria for Jointly Testing Equality and Inequality Restrictions, *Econometrica*, 54:1243-1246.

Koopmans, T. C. (1951). An Analysis of Production as an Efficient Combination of Activities, In, T. C. Koopmans (ed), Activity Analysis of Production and Allocation, Cowles Commission for Research in Economics, Monograph No. 13, John Wiley and Sons Inc, New York.

Kopp, R. J. and W. E. Diewert (1982). The Decomposition of Frontier Cost Function Deviations into Measures of Technical and Allocative Efficiency, *Journal of Econometric*, 19: 319-331.

Kumbhakar, S. C. (1994). Efficiency Estimation in a profit Maximizing Model using Flexible Production Function, *Agricultural Economics*, 10:143-152.

Laha, A. and P. K. Kuri (2011). Measurement of Allocative Efficiency in Agriculture and its Determinants: evidence from Rural West Bengal, India, International *Journal of Agricultural Research,* 6(5): 377-388.

Lawal, B. O., J. O. Saka, A. Oyegbami and I. O. Akintayo (2004). Adoption and Performance Assessment of Improved Maize Varieties among Smallholder Farmers in Southwest Nigeria , *Journal of Agriculture and Food Information*, 6(1): 35-47.

Lee, L. F. and W. G. Tyler (1978). The Stochastic Frontier Production Function and Average Efficiency, *Journal of Econometrics*, 7(3): 385-389.

Lingard, J., L. Castillo and S. Jayasuriya (1983). Comparative Efficiency of Rice Farmers Central Luzon in the Philippines, *American Journal of Agricultural Economics*, 34: 163-173.

Mahadi E. (2005).Farmers' Evaluation, Adoption And Sustainable Use Of Improved sorghum Varieties In Jijiga Woreda, Ethiopia Msc. Thesis (Unpublished) Submitted to School of Graduate Studies of Alemaya University, Ethiopia.

Marra, M. C., B. J. Hubbell and G. A. Carlson (2001). Information Quality, Technology Depreciation and Bt Cotton Adoption in the South East, *Journal of Agricultural and Resource Economics*, 26(1): 158-175.

Marsh, S. P.(2010).Adopting Innovations in Agricultural Industries, paper presented at the ABARE Outlook Conference, Canberra.

Mbanasor, J. A. and K. C. Kalu (2008). Economic Efficiency of Commercial Vegetable Production System in Akwa Ibom State, Nigeria: A Translog Stochastic Frontier Cost Function Approach, *Tropical and Subtropical Agroecosystems*, 8(3): 313-318

McConnell, K. E. (1983). An Economic Model for Soil Conservation, *American Journal of Agricultural Economics*, 65(1): 83-89.

Meeseun, W. and J. van den Broeck (1977). Efficiency Estimation for Cobb-Douglass Production Functions with Composed Error, *International Economic Review*, 18: 435-444.

Mesfin A.(2005). Analysis of factors Influencing Adoption of Triticale and its Impact.The Case Farta Wereda. M.Sc. Thesis (Unpublished) Submitted to School of Graduate Studies of Alemaya University, Ethiopia.

MihiretuT. A.(2008). Farmers' Evaluation Adoption of Improved Onion Production Package in Fogera District, South Gondar, Ethiopia. M.Sc. Thesis (Unpublished) Submitted To School of Graduate Studies of Haramaya University, Ethiopia.

Million T. and Belay K. (2004). Determinants of Fertilizer Use in Gununo Area,Ethiopia. Pp 21-31. In Tesfaye Z., Legesse D. and Dawit A. (eds).*Agricultural Technology Evaluation, Adoption and Marketing*. Proceedings of the Workshop held to discuss the Socio-Economic Research Results of 1998-2002. 6-8. August, 2002. Addis Ababa, Ethiopia.

Moses J. and E. F. Adebayo (2007). Efficiency Factors Determining Rain-fed Rice Production in Ganye Local Government Area, Adamawa State, *Journal of Sustainable Development in Agriculture and Environment*, 3: 20-30.

Mukherjee, C., H. White and M. Wuyts (1998). *Econometrics and data Analysis for developing Countries,* Routledge, London.

Mulugeta E., K. Belay and D. Legesse (2001). Determinants of Adoption of Physical Soil Conservation Measures in Central Highlands of Ethiopia. The Case of Three Districts of North Shewa. *Agrekon*, 40(3). 293-315

National Agricultural Extension and Research Liaison Services (NAERLS)/Projects Coordinating Unit (PCU) (2004). Field Assessment of 2004 Wet Season Agricultural production in Nigeria, NAERLS, Ahmadu Bello University, Zaria, Nigeria.

Nkonya, E., S. Ted and N. David (1997). Factors affecting Adoption of Improved Maize Seed and Fertilizer in Northern Tanzania. *Journal of Agricultural Economics*,48 (1) 1-12.

Norris, P. E. and S. E. Batie (1987). Virginia Farmers' Soil Conservation Decisions: An Application of Tobit Analysis, *Southern Journal of Agricultural Economics*, 19(1): 79-80.

Nossal, K.(2011).From R&D to Productivity Growth: Investigating the role of Innovation Adoption in Australian agriculture, ABARES report for the Rural Industries Research and Development Corporation, Canberra.

Nwagbo, E. C. (2000). Agricultural Policy in Nigeria: Challenges for the 21st Century, *Journal of Tropical Agriculture, Food, Environment and Extension*, 1(1): 54-61.

Obwona, M. (2000). Determinants of Technical Efficiency Differentials amongst Small and Medium Scale Farmers in Uganda: A Case of Tobacco Growers, Final research Report Presented at the Biennial African Economic Research Consortium (AERC) Workshop, Nairobi, Kenya.

OECD 2005, *Oslo Manual*, OECD/Eurostat, Paris.

Ogar, C. U., I. C. Idiong, D. S. Udom and S. O. Abang (2002). Allocative Efficiency of Labour Resource in Swamp Rice Production in Obudu Local Government Area, Cross River State, Nigeria, *Global Journal of Agricultural Sciences* 1(2): 143-148.

Ogundari, K. and S. O. Ojo (2006). An Examination of Technical, Economic and Allocative Efficiency of Small Farm: The Case Study of Cassava Farmers in Osun State of Nigeria, Journal of Central European Agriculture, 7 (3): 423-432.

Ogundele O. O. and V. O. Okoruwa (2006). Technical Efficiency Differentials in Rice Production Technologies in Nigeria AERC Research Paper No 154, African Economic Research Consortium (AERC) Nairobi, Kenya.

Ohajianya, D. O. and C. E. Onyenwaku (2003). Analysis of Costs and Returns in Rice Farming by Farm Size in Ebonyi State, Nigeria, *Journal of Agriculture and Social Research*, 3(1): 29-39.

Ojanuga, A. G. (2006). *Agro-ecological Zones of Nigeria Manual*, edited by F. Berding and V. O. Chude, A Publication of National Special Programme for Food Security, Abuja, Nigeria.

Ojo, S. and P. B. Imoudu (2000). Productivity and Technical Efficiency: A Comparative Analysis of Oil Palm Farms in Ondo State, Nigeria, *Journal of Agriculture, Forestry and Fisheries*, 1: 40-46.

Okoruwa, V. O., O. O. Ogundele and B. O. Oyewusi (2006). Efficiency and Productivity of Farmers in Nigeria: A Study of Rice Farmers in North Central Nigeria, Poster Paper Prepared for Presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia, 12th-18th August.

Opia, O. P. B. and W. J. Oyaide (2007). Transnational Entrepreneurs, Temporary Returns and Agricultural Enterprise Development in Nigeria, *In* Haruna U, Jibril S. A., Mancha Y. P and Nasiru M. (eds) *Consolidation of the Growth and Development of Agricultural Sector*, Proceedings of the 9th Annual Conference of Nigerian Association of Agricultural Economists held in Bauchi, from 5th to 8th November, Pp 261-269.

Oredipe, A. A. and J. A. Akinwumi (2000). Resource Productivity and Efficiency among Farmers adopting Improved Maize Technology in Ogun State, Nigeria, *Nigerian Agricultural Development Studies*1: 27-42.

Pannell, D. J., G. R. Marshall, N. Barr, A. Curtis, F. Vanclay and R. Wilkinson (2006). Understanding and Promoting Adoption of Conservation Practices by Rural Landholders, *Australian Journal of Experimental Agriculture*, 46 (11): 1407–24.

Perrin, J. and D. Winklemann (1976). Impediments to Technology Progress on Small versus Large Farms, *American Journal Agricultural Economics*, 58(5): 888-894.

Pindyck, R. S. and D. L. Rubinfeld (1997). *Econometric Models and Economic Forecasts*, 4th Edition, McGraw-Hill International Edition, New York Pp 298-329.

Prokopy, L. S., K. Floress, D. Klotthor-Weinkauf and A. Baumgart-Getz (2008). Determinants of Agricultural Best Management Practice Adoption: Evidence from the Literature, *Journal ofSoil and Water Conservation*, 63:300–11.

Rahman, S. A. and J. F. Alamu (2003). Estimating the Level of Women Interest in Agriculture: An Application of Logistic Regression Model, *The Nigerian Journal of Scientific Research*, 4(1): 45-49.

Rahmeto N.(2007). Determinants of Improved Haricot Bean Production Package in Alaba Special Woreda, Southern Ethiopia. M.Sc. Thesis (Unpublished) Submitted to School ofGraduate Studies of Haramaya University, Ethiopia.

Ray, G. L. (2001). *Extension Communication and Management*. 2nd Edition. Naya Prokash, Calcutta.pp.65-72.

Readson T. and S. A. Vosti (1997). Policy Analysis of Conservation Investments: Extension of Traditional Technology Adoption Research, *In* Readson, T. and Vosti, S. A. (eds), *Sustainability, Growth and Poverty Alleviation*, The John Hopkins University Press, Baltimore.

Richmond, J. (1974). Estimating the Efficiency of Production, *International Economic Review*, 15: 515-521.

Rogers, E. M. and F.F. Shoemaker, (1971). *Communication of Innovation: A Cross-cultural Approach*, Second Edition. The Free Press, New York.

Rola, A. and J. T. Quintana-Alejandrino (1993). Technical Efficiency of Philippine Rice Farmers in Irrigated, Rainfed Lowland and Upland Environments: A Frontier Production Function Analysis, *Philippine Journal of Crop Science*, 18: 56-59.

Sadoulet, E. and A. de Janvry (1995). *Quantitative Development Policy Analysis*, The John Hopkins University Press, Baltimore, Mary land.

Schmidt, P. (1976). On the Statistical Estimation of Parametric Frontier Production Functions, *Review of Econometric Statistics*, 58: 238-239.

Schultz, T. W. (1964). *Transforming Traditional Agriculture*, Yale University Press, New Haven.

Schultz, T. W. (1975). The Value of the Ability to Deal with Disequilibria, *Journal of Economic Literature*, 13(3): 827-846.

Seyoum, E. T., G. E. Battese and E. M. Fleming (1998). Technical Efficiency and Productivity of Maize Producers in Eastern Ethiopia: A Study of Farmers and Within and Outside the Sasakawa-Global 2000 Project, *Agricultural Economics*, 19:341-348.

Shapiro, K. (1983). Efficiency Differentials in Peasant Agriculture and their Implication for Development Policies, *Journal of Development Studies*, 19: 179-190.

Sharma, K. R., P. Leung and H. M. Zalleski (1999). Technical, Allocative and Economic Efficiencies in Swine Production in Hawaii: A Comparison of Parametric and Non-parametric Approaches *Agricultural Economics*, 20(1): 23-35.

Shaw, A. B. (1985). Constraints in Agricultural Innovation Adoption, *Economic Geography*, 61(1): 25-45.

Shehu, J. F. and S. I. Mshelia (2007). Productivity and Technical Efficiency of Small-Scale Rice Farmers in Adamawa State, Nigeria, *Journal of Agriculture and Social Sciences*, 3(4): 117-120.

Shehu, J. F., S. I. Mshelia and A. K. Tashikalma (2007). Analysis of Technical Efficiency of Small-Scale Rain-fed Upland Rice Farmers in North-West Agricultural Zone of Adamawa State, Nigeria, *Journal of Agriculture and Social Sciences*, 3(4): 133-136.

Shiyani, R. L., P. K. Joshi, M. Ashokan and M. C. S. Bantilan (2000). Adoption of improved Chickpea Varieties: Evidences from Tribal Region of Gujarat. *Indian Journal of Agricultural Economics*, 55 (2): 159-171.

Simtowe, F., M. Zeller and A. Diagne (2009). The impact of credit constraints on the adoption of hybrid Maize in Malawi, Contributed Paper Prepared for Presentation at the International Association of Agricultural Economists Conference held from august 16-22 in Beijing, China

Singh, I., L. Squire and J. Strauss (1986). *Agricultural Household Models: Extensions, Applications and Policy*, Johns Hopkins University Press, Baltimore.

Singh, S., T. Coelli and E. Fleming (2000). Measurement of Technical, Allocative and Economic Efficiency in Indian Dairy Processing Plants: An Input Distance Function Approach, CEPA Working Papers, Department of Econometrics, University of New England, Armidale, Australia.

Spielman, D. J. and R. Birner (2008).How Innovative is your Agriculture? Using Innovation Indicators and Benchmarks to strengthen National Agricultural Innovation Systems, Agriculture and Rural Development Discussion Paper no. 41, World Bank, Washington, D.C.

Squires, D. and S. Tabor (1991). Technical Efficiency and Future Production Gains in Indonesian Agriculture, *The Development Economics*, 29: 258-270.

Swinston, S. M. and R. Quiroz (2003a). Is Poverty to Blame for Soil, Pasture and Forest Degradation in the Peru's Altiplano? *World Development* 31(11): 1903-1919.

Swinston, S. M. and R. Quiroz (2003b). Poverty and the Deterioration of Natural Soil Capital in the Peruvian Altiplano, *Environment, Development and Sustainability* 5: 477-490.

Tadesse, B. and S. Krishnamoorthy (1997). Technical Efficiency in Paddy Farms of Tamil Nadu: An Analysis based on Farm Size and Ecological Zone, *Agricultural Economics,*16: 185-192.

Taha M.(2007). Determinants of the adoption of improved onion production package in Dugda Bora district, East Shewa, Ethiopia. M.Sc. Thesis (Unpublished) Submitted To School of Graduate Studies of Haramaya University, Ethiopia.

Taylor, T. G., H. E. Drummond and A. T. Gomes (1986). Agricultural Credit Programs and production Efficiency: An Analysis of Traditional Farming in Southeastern Minas Gerais, Brazil, *American Journal of Agricultural Economics*, 68: 110-119.

Tchale, H. (2009). The Efficiency of Smallholder Agriculture in Malawi, *AFJARE*, 3(2): 101-121.

Techane A.(2002). Determinants of Fertilizer Adoption in Ethiopia. The Case of Major Cereal Producing Areas. M.Sc. Thesis (Unpublished) Submitted to School of Graduate Studies of Alemaya University, Ethiopia.

Tesfaye Z., T. Girma, D. Tanner, H. Verkuijl, A. Agidie, and W. Mwangi(2001).Adoption of Improved Bread Wheat Varieties and Inorganic Fertilizer by Small Scale Farmers in Yelma Dansa and Farta Districts of Northern Ethiopia. Mexico, D.F. Ethiopian Agricultural Research Organization (EARO) and International Maize and Wheat Improvement Center (CIMMYT).

Tiamiyu, S. A., J. O. Akintola M. A. Y. and Rahji (2009). Technology Adoption and Productivity Difference among Growers of New Rice for Africa in Savanna Zone of Nigeria, *Tropicultura*, 27(4): 193-197.

Timmer, C. P. (1971). Using a Probabilistic Frontier Function to Measure Technical Efficiency, *Journal of Political Economics*, 79: 776-794.

van de Ban, A.W. and Hawkins H. S.(1998). *Agricultural Extension*, 2nded. Blackwell Science The Netherlands, 249p

Weir, S. and J. Knight (2000). Education Externalities in Rural Ethiopia: Evidence from Average and Stochastic Frontier Production Functions, *Working Paper CSAE* WPS/2000.4, Centre for the Study of African Economies, University of Oxford.

Xu, X. and S. R. Jeffrey (1998). Efficiency and Technical Progress in Traditional and Modern Agriculture: Evidence from Rice Production in China, *Agricultural Economics*, 18: 117-165.

Yao, S. and Z. Liu (1998). Determinants of Grain Production and Technical Efficiency in China, *Journal of Agricultural Economics*, 49(2):171-184.

Yishak G.(2005). Determinants of Adoption of improved Maize Technology in Damote Gale Woreda, Wolaita, Ethiopia. M.Sc. Thesis (Unpublished) Submitted to School of Graduate Study of Alemaya University, Ethiopia.

Appendix 1

INTERVIEW SCHEDULE

UNIVERSITY OF NIGERIA, NSUKKA
FACULTY OF AGRICULTURE
DEPARTMENT OF AGRICULTURAL ECONOMICS

Dear respondent,

I am a Ph.D student of the above stated institution. I am carrying out a research entitled "Production Efficiency Differentials and Innovative Behaviour among Rice Farmers in Northeastern Nigeria". You have been chosen as one of the respondents. Completion of this interview schedule will take small amount of your time but your responses will be of immense importance to my research. Your cooperation in responding to questions in this interview schedule will be highly appreciated. You are guaranteed complete anonymity as an individual respondent and the information provided will be used for the purpose of research only.

Thank you.

SHEHU, JACOB FINTAN

A. SOCIO-ECONOMIC CHARACTERISTICS OF FARMERS

1. Name of farmer……………………………………………….Age:………………….

2. State:……………………L.G.A:……………………… Village:………………………

3. Gender: Male [ ] Female [ ]

4. Marital status
   Married [ ]
   Single [ ]
   Divorced [ ]
   Widowed [ ]

5. Family Size
   Number of wives:………………………..
   Number of children:……………….........
   Number of other dependants:…………….

6. Educational level
   Non formal [ ]
   Primary [ ]
   Post-primary [ ]
   Post-secondary [ ]
   Others (please specify)…………………………………………….

7. Membership of farmers association Yes [ ] No [ ]

8. If yes to question 6 above, please give the name of the association:………………………
   …………………………………………………………………………………………..

9. Major occupation:………………………………………………………………….

10. Other occupation(s):……………………………………………………………….

B. DATA ON RICE FARMING ACTIVITIES

11. Years of rice farming experience:……………………………………………………

12. Total land holdings:……………………………………………………………….

13. Give the approximate size of your rice farm (in hectares):………………………………..

14. How did you acquire your farmland
    Bought [ ]
    Leased to me [ ]
    Given to me [ ]
    Inherited [ ]
    Others (please specify)……………………..

15. If bought or being rented, state the cost per year (in Naira)………………………………..

16. Give the approximate distance of your farm from your house (in kilometers)…………….

17. Apart from rice, which of the following crop (s) do you cultivate?

Sorghum [ ] Maize [ ] Millet [ ] Cowpea [ ]
Cotton [ ] Tomato [ ] Pepper [ ] Okra [ ]
Groundnut [ ] others (please specify)……………………………………..
…………………………………………………………………...

18. Do you make use of family labour on your rice farm? Yes [ ] No [ ]

19. If yes to question 17 above, fill the table below:

Data on family labour used

Farm operation	Adult male			Adult female			Children		
	Number engaged	*Number of days worked*	*Number of hours worked per day*	*Number engaged*	*Number of days worked*	*Number of hours worked per day*	*Number engaged*	*Number of days worked*	*Number of hours worked per day*
Land clearing									
Planting									
Transplanting									
Weeding									
Fertilizer application									
Bird scaring									
Harvesting, threshing, winnowing and bagging									

20. Do you make use of hired labour on your rice farm? Yes [ ] No [ ]

21. If yes to question 20 above, fill the table below:

Data on hired labour used

Farm operation	Adult male				Adult female				Children			
	Number engaged	*Number of days worked*	*Number of hours worked per day*	Wage paid	*Number engaged*	*Number of days worked*	*Number of hours worked per day*	Wage paid	*Number engaged*	*Number of days worked*	*Number of hours worked per day*	Wage paid
Land clearing												
Planting												
Transplanting												
Weeding												
Fertilizer application												
Bird scaring												
Harvesting, threshing, winnowing and bagging												

C. DATA ON INPUTS USED IN RICE PRODUCTION

22. Fill the table below where applicable.

INPUT		
Seed	Source	
	Quantity used (kg)	
	Cost involved (₦)	
	Transport cost (₦)	
Fertilizer	Source	
	Quantity used (kg)	
	Cost involved (₦)	
	Transport cost (₦)	
Herbicide	Source	
	Quantity used (kg)	
	Cost involved (₦)	
	Transport cost (₦)	
Pesticide	Source	
	Quantity used (kg)	
	Cost involved (₦)	
	Transport cost (₦)	

23. Which of the following did you use to prepare your farmland?
Tractor [ ] Work bulls [ ] Manual labour [ ]

24. What is the cost involvement of preparing your farmland (₦)……………………………

D. DATA ON FARM TOOLS OWNED

25. Fill the table below where applicable

Asset	Number owned	Cost/Unit	Year of purchase	Approximate life span
Hoe				
Cutlass				
Sprayer				
Rake				
Wheel barrow				
Others (please specify) i. ii. iii.				

E. DATA ON YIELD, STORAGE AND MARKETING

26. Fill the following table

Paddy yield (kg)	
Quantity consumed (kg)	
Quantity given out as gift (kg)	
Quantity sold (kg)	
Price/100kg bag	
Transport cost incurred	
Amount spent on storage	
Cost of empty bags	
Other costs incurred (if any) i. ii. iii. iv.	

27. Do you have ready market for your farm produce? Yes [ ] No [ ]

28. How did you dispose your farm produce?

On the farm immediately after harvest [ ]
Dealers buy at home [ ]
Market [ ]
Through cooperative society [ ]

Others (please specify)……………………………………………………………..

29. Are you satisfied with prices offered Yes [ ] No [ ]

30. If no to question 34 above, make suggestions for improvement

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

F. DATA ON SOURCE OF FINANCE FOR FARM OPERATIONS

31. Where do you get money for your farm operations?

Personal savings [ ]
Borrowed [ ]

Others (please specify)……………………………………………………………...

32. If borrowed, kindly fill the table below.

Source	***Amount (~~N~~)***	***Interest rate charged (%)***
Friend (s)		
Relatives		
Money Lenders		
Commercial Banks		
Nigeria Agricultural Cooperatives and Rural Development Bank		
Others (please specify) i. ii.		

33. Do you encounter difficulties before accessing the loan facility?

Yes [ ]
No [ ]

34. How would you rate the interest rate charged on the loan facility?

Low [ ]
Moderate [ ]
High [ ]

35. Does the lending agency monitor your farm operations Yes [ ] No [ ]

G. DATA ON EXTENSION SERVICE RECEIVED

36. Do you have access to extension service? Yes [ ] No [ ]

37. If yes, give an approximate number of times an extension agent visit you……………….

38. Does the extension agent bring any production recommendation?

Yes [ ]
No [ ]

39. If yes to question 45 above, which of the following (s)?

Use of improved rice seed [ ]
Use of correct spacing [ ]
Fertilizer application (basal and top dressing [ ]
Use of herbicides [ ]
Use of insecticides [ ]
Others (please specify)…………………………………………………………...

…………………………………………………………………………………………

……………………………………………………………………………………......

40. Which of the recommended farm practice (s) in question 46 above do you adopt?

Use of improved rice seed [ ]

Fertilizer application (basal and top dressing [ ]

Use of herbicides [ ]

Use of insecticides [ ]

Others (please specify)…………………………………………………………...

…………………………………………………………………………………………

……………………………………………………………………………………......

41. How would you describe the cost of adopting the recommendations?

High [ ]

Moderate [ ]

Low [ ]

42. How effective were the services rendered by the extension agent?

Poor [ ]
Fair [ ]
Good [ ]
Excellent [ ]

H. DATA ON CONSTRAINTS ASSOCIATED WITH RICE PRODUCTION

43. Which of the following affect your performance in rice production?

Inadequate rainfall [ ]
Low paddy rice prices [ ]
Pests and disease infestation [ ]
Inadequate credit facilities [ ]
Soil degradation [ ]
Inadequate research and extension support [ ]
Inaccessibility to cheap farm inputs [ ]
Land tenure problems [ ]
Shortage of labour [ ]
Lack of storage facilities [ ]
Others (please specify)………………………………………………………………

……………………………………………………………………………………….

……………………………………………………………………………………….

44. Suggest ways of alleviating the above constraints

…………………………………………………………………………………………….

…………………………………………………………………………………………….

…………………………………………………………………………………………….

…………………………………………………………………………………………….

…………………………………………………………………………………………….

…………………………………………………………………………………………….

Appendix 2: Variable Inflation Factor (VIF) for Continuous Explanatory Variables

Variable	Tolerance	VIF
Income	0.776	1.289
Age	0.740	1.351
Education	0.942	1.062
Experience	0.983	1.017
Farm size	0.879	1.138
Family size	0.706	1.416
Extension contact	0.693	1.443

Appendix 3: Phi coefficients for dummy variables

Variable	1	2	3
Membership of cooperative Society	1		
Access to credit	-0.041	1	
System of land ownership	-0.021	-0.078	1