UNIVERSITY FOR DEVELOPMENT STUDIES

AGRICULTURAL TECHNOLOGY ADOPTION AND MARKET PARTICIPATION AMONG SMALLHOLDER RICE FARMERS IN NORTHERN GHANA

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BY

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FEBRUARY, 2019

DECLARATION

I, the undersigned hereby declare that this thesis entitled "**Agricultural Technology Adoption and Market Participation among Smallholder Rice Farmers in Northern Ghana**" is the result of my own original work which has not been submitted for another degree in this University or elsewhere.

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(Student's Name)	**(Signature)**	**(Date)**

Supervisors

We, hereby declare that the preparation and presentation of the thesis was supervised in accordance with the guidance on supervision of thesis laid down by the University for Development Studies.

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ABSTRACT

In recent years the contribution of rice production from northern Ghana to national production has declined, thereby raising concerns of productivity. This study is carried out to examine agricultural technology adoption and market participation among smallholder rice farmers in northern Ghana. A sample size of 429 rice farming households from the Northern, Upper East and Upper West regions was used for the study. Multivariate probit model was used to estimate adoption of improved rice production technologies. Multivariate Distance Matching method was used to evaluate the effect of improved variety on yield of rice. The level and intensity of output market participation were analysed using the Quantile regression and Heckman model respectively. The results indicate low technology adoption rates. Improved rice variety was the most adopted technology followed by chemical fertiliser usage, herbicide application, dibbling or drilling of seed and bunding. Adoption of the production technologies were influenced by family labour, land ownership, number of rice plots, access to training, soil type, household expenditure and distance to parcel. Adopters of improved rice varieties recorded higher yields per acre compared with non-adopters. Generally, average yield of rice was low and traditional rice varieties are still preferred by some farm households. Market participation was high with majority of farm households selling a greater proportion of their output. Size of rice plot, cultivation of improved variety, yield per acre, selling price and training on rice production influenced output market behaviour of rain fed rice farm households. The study recommends that national agricultural subsidy programmes be strengthened and expanded to include other complementary technologies of rice farming. Government and research institutions should promote extension and training to stimulate adoption of improved technology. Market information delivery and market infrastructure development should be improved.

DEDICATION

This thesis is dedicated to my family and supervisors enabling such a study to take place.

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LIST OF ACRONYMS

AAGDS	Accelerated Agricultural Growth and Development Strategy
AfDB	African Development Bank
AGRA	Alliance for a Green Revolution in Africa
ATT	Agricultural Technology Transfer
CCVRRG	Catalogue of crop varieties released and registered in Ghana
CIMMYT	International Maize and Wheat Improvement Center
CSIR	Council for Scientific and Industrial Research
FAO	Food and Agriculture Organisation
FASDEP	Food and Agricultural Sector Development Policy
GAP	Good Agricultural Practices
GoG	Government of Ghana
GPRS I	Ghana Poverty Reduction Strategy I
GPRS II	Growth and Poverty Reduction Strategy II
GRIB	Ghana Rice Inter-Professional Body
GSS	Ghana Statistical Service
GSSP	Ghana Strategy Support Program
IFAD	International Fund for Agricultural Development
IFDC	International Fertilizer Development Center
IFPRI	International Food Policy Research Institute
IMR	Inverse Mills Ratio
IRRI	International Rice Research Institute
JICA	Japan International Cooperation Agency

MDM	Multivariate Distance Matching
METASIP	Medium Term Agriculture Sector Investment Plan
MiDA	Millennium Development Authority
MMDA	Metropolitan, Municipal and District Assemblies
MoFA	Ministry of Food and Agriculture
MoFEP	Ministry of Finance and Economic Planning
MT	Metric tonnes
MVP	Multivariate Probit
NAFCO	National Food Buffer Stock Company
NERICA	New Rice for Africa
NGO	Non-Governmental Organisation
NRDS	National Rice Development Strategy
OLS	Ordinary Least Square
PPRS	Plant Protection and Regulatory Services
PSM	Propensity Score Matching
SADA	Savannah Accelerated Development Authority
SARI	Savanna Agricultural Research Institute
TLU	Tropical Livestock Units
UDS	University for Development Studies
USAID	United States Agency for International Development
USDA	United States Department of Agriculture

CHAPTER ONE

INTRODUCTION

1.1 Background

Agriculture is a livelihood as well as an economic enterprise employing about 60 percent of the world's population and is intimately linked with food security, health, and nutrition through direct consumption and market linkages (Poole, 2017). Smallholder agriculture is one of the principal economic occupations in the world and is the main source of income and employment for 70 percent of the world's poor who live in rural areas and account for 60 percent of global agriculture (Poole, 2017). Nonetheless, majority of these smallholder farm households account for the highest incidence of workers living with their families below the poverty line (FAO, 2012). Estimates show that there are about 500 million farms globally which are being cultivated by smallholder farm households with more than 2 billion people making their livelihood from these farms (Abdullah, Rabbi, Ahamad, Ali, Chandio, Waqar, Ilyas and Din, 2017; FAO, 2012). In Africa, agriculture remains a strategic sector and its wealth directly affects economic development, food security, poverty alleviation and social welfare, particularly of countries in Sub-Saharan Africa whose agriculture is dominated by smallholder farmers (Mango, Makate, Tamane, Mponele, and Ndengu, 2017; Todaro and Smith, 2012). In Africa, smallholder farm households are the central source of food supply providing up to 80 percent of the total food stock and are therefore central to an inclusive development process with significant contribution to food security (Abdullah *et al.*, 2017; Arias, Hallam, Krivonos and Morrison, 2013).

In Ghana, agriculture plays a key role in economic development, food security and poverty alleviation for the growing population. The agricultural sector contributes significantly (18.3 percent) to gross domestic product and a major income source for 44 percent of the labour force (GSS, 2018; MoFA, 2016). The importance of the agricultural sector is of more concern, particularly in rural areas where households primarily depend on agriculture for their livelihood. Agriculture is predominantly on a smallholder basis in Ghana and farmers (mostly rural dwellers) generally undertake rain fed agriculture with majority (90 percent) of farm holdings being less than 2 hectares in size (MoFA, 2016; Akudugu, Nyamadi and Dittoh, 2016; MoFA, 2011). The implication of this dominance of smallholders in Ghana's agricultural sector is that, no meaningful course of action to augment the progress of the sector can overlook these farmers.

Given that rice is one of the important food crops in the world and ranks second in terms of area and production reveals the contribution of smallholder farms to global food supply (Arias *et al*., 2013). Rice production plays a principal role in providing food security for poor households in both rural and urban locations in Africa (Ragasa and Chapoto, 2017), given that nearly 20 million farmers in Sub-Saharan Africa grow rice and about 100 million people depend on it for their livelihoods (Nwanze, Mohapatra, Kormawa, Shellemiah and Bruce-Oliver, 2006). Over the years, rice has become an ideal substitute for most traditional coarse grains and root and tuber crops in Sub-Saharan Africa due to the changing food preferences in both urban and rural areas (Asante, Wiredu, Martey, Sarpong and Mensah-Bonsu, 2014). Consumption of rice in West Africa increased from the fourth most consumed cereal to the first within fourteen years (1990 to 2014), (USDA, 2015). Continual population growth coupled with rapid urbanisation is further stimulating demand for rice in the region. The surge in demand for rice in Africa is evident given that many strategic food security planning policies in African countries have focused on rice as a food security crop (Norman and Otoo, 2002).

Rice is fast becoming a cash crop for many smallholder farmers in recent years (Darfour and Rosentrater, 2016; Asuming-Brempong and Osei-Asare, 2007), as well as being an important food staple for both rural and urban communities across Ghana. Rice is the second most important staple cereal after maize, with substantial and continuing growth in rice consumption over the last two decades (MoFA, 2016; MiDA, 2010). The importance of rice is evident in both national and agricultural development policies, plans and strategies to develop the country. The Ghana Poverty Reduction Strategy (GPRS I), Growth and Poverty Reduction Strategy (GPRS II), Food and Agricultural Sector Development Policy (FASDEP I & II), Medium Term Agriculture Sector Investment Plan (METASIP I & II), National Fertilizer Subsidy programme, National Rice Development Strategy (NRDS), Accelerated Agricultural Growth and Development Strategy (AAGDS), and the recent "Planting for Food and Jobs" programme have all featured rice as one of the targeted food security crops (MoFA, 2017).

The National Rice Development Strategy aims to double rice production by the close of 2018 with 10 percent annual increases while the recent “Planting for Food and Jobs” programme is expected to increase the production of rice by 49 percent from current production level (MoFA, 2017). Apparently, rice is a key economic commodity in Ghana with a high potential to improve self-sufficiency hence have received reasonable attention by policy makers in recent times.

However, Ghana as in the case of most countries in Sub-Saharan Africa is not self-sufficient in rice production and therefore rely on imported rice to make up for the gap in domestic demand (MoFA, 2016; MoFA, 2009; Aggrey-Fynn, 1999). Annual per capita consumption of rice has doubled over a decade (from 15 kilogram in 2005 to 32 kilogram in 2015), (MoFA, 2016), and rice demand is projected to grow persistently in the medium term. Estimates show that imported rice comprises about 62 percent of the quantity consumed in Ghana which is widening the import penetration ratio (MoFA, 2016; Amanor-Boadu, 2012) and putting much pressure on foreign currency reserves and food security. Additionally, domestic rice supplies have not kept up with changing consumer preferences towards long grain aromatic rice. Ghana has experienced average shortfalls in domestic rice supplies of 57.87 percent (42.13 percent self-sufficient) in recent years (MoFA, 2016; FAO, 2015). The 2015/2016 food balance sheet shows that the estimated net consumption of milled rice (914,016 MT) exceeded available total domestic production of milled rice (385,087 MT) available for human consumption in Ghana (MoFA, 2016). Meanwhile, Ghana's population and per-capita consumption of rice is expected to be on the ascendency. If improvement in yields are not kept in pace with increase in consumption in the coming years, then a mixture of rice area expansion and imports will be needed in addition to yield gap closure to meet the growing demand for rice.

In Ghana, rain fed rice production which is widely practised in northern Ghana contributes 84 percent of national production compared with 16 percent production from irrigation (MoFA, 2014). Average yield of rice under rain fed production is generally low (2.75 MT/ha) and fall far below potential yield (6 MT/ha), which is most often associated with low adoption of improved technologies (Ragasa and Chapoto, 2017; MoFA, 2016; Ragasa, Dankyi, Acheampong, Wiredu, Chapoto, Asamoah and Tripp, 2013). Against this background, many development programmes and projects aimed at promoting local rice production to increase yields via the adoption of improved agricultural technologies have been implemented across Ghana. Most of the implemented interventions focused on rice sector policies, infrastructure, research, credit, marketing in addition to dissemination of improved rice production and postharvest technologies across districts in northern Ghana.

It is obvious that smallholder rice farmers in northern Ghana have benefited from the dissemination of improved rice production technologies by development programmes and projects (Asante *et al.*, 2014; Ragasa *et al.*, 2013; Wiredu *et al.*, 2010; Faltermeier, 2007; Langyintuo and Dogbe, 2005; Al-hassan, Sarpong and Al-Hassan, 2004), aimed at increasing yields and incomes of farmers. Adoption of promoted technologies is expected to translate into higher yields and incomes by means of increased output participation to improve the wellbeing of smallholder farm households.

1.2 Problem Statement

Smallholder agriculture is recognised as an important development tool for achieving the Sustainable Development Goals in developing countries. However, majority of smallholder farmers rely on traditional methods of production which has lowered the level of productivity and provide less opportunities for farmers to participate in the output market (Poole, 2017; Mwangi and Kariuk, 2015).

Northern Ghana, compared to the fast developing and urbanising south is relatively poor, dry, and politically unstable. Nonetheless, in last years, the three regions in northern Ghana (the "SADA North") have received much government and donor attention in the form of agricultural subsidies and social support through many agricultural interventions. The northern savanna zone is considered as Ghana's "breadbasket" and initiatives are being designed to transform the north into a more stable and prosperous area, with a focus on smallholder production of staple grains like rice to improve agricultural yield and market connectivity (USAID, 2012).

The Ghana National Rice Development Strategy was established in 2009 to curtail over dependence on rice importation in order to realise domestic food security, improve income, and reduce the incidence of poverty. The goal of the strategy is to double rice production by 2018 with a 10 percent yearly growth. Over a decade, domestic rice production rose by 7 percent (2004 to 2014), and recently, domestic rice production has been increasing at 7.5 percent a year (since 2009). However, a greater proportion (6 percent) of this growth in production is as a result of area expansion and only 1.5 percent can be attributed to yield improvement (Ragasa and Chapoto, 2017; Ragasa, Takeshima, Chapoto and Kolavali, 2014). Indicating clearly that increase in rice production is mainly driven by area expansion rather than close in the yield gap.

Though rice is grown in all ten regions of Ghana, northern Ghana accounts for over 60 percent of land area devoted to rice cultivation (MoFA, 2016). Previously the Northern and the Upper East regions were the top two regions that contributed 37 percent and 27 percent respectively to domestic rice production followed by the Volta region with 15 percent (MoFA, 2011). Recent statistics have however showed that there has been drastic decrease in the contribution of rice production by Northern and Upper East regions contributing 27.83 and 18.96 percent respectively with Volta region producing 30.46 percent, making her the leading producer (MoFA, 2016). Between 2011 to 2016 an average of a 10 percent decline in Northern Ghana's contribution to domestic rice production is observed, yet northern Ghana hosts the largest acreage under rice production. In addition, no district in northern Ghana is part of the top ten (10) yield performing districts in Ghana, with only four (4) districts performing slightly above the national average yield of 2.75 metric tonnes per hectare out of thirty two (32) rice producing districts in northern Ghana (MoFA, 2016).

The low levels of productivity recorded in northern Ghana is attributed to the reliance of farmers on rainfall, the subsistence nature of most farm households and inadequate use of other improved rice production technologies (Ragasa and Chapoto, 2017; Bruce, Donkoh and Ayamga, 2014; Ragasa, 2013; Dzudzor, 2013; Wiredu *et al.*, 2010). Despite the expected gains from the use of improved rice technologies to increased yields and incomes, rice productivity still remains low in northern Ghana. Low productivity constrains smallholder farmer's ability to generate market surplus which motivates output market participation.

Governments, development agencies, development partners and extension workers have long known that the success of any project depends, in part, on whether farmers adopt the offered technologies and, if they do, whether those farmers adopt the technologies in an ideal combination and for the prescribed length of time needed to achieve the desired results. Many development partners and projects therefore promote income-generating projects as a way of encouraging growth through increased agricultural production, the introduction of technology and an opportunity to participate and benefit from the output market.

In Ghana, agricultural related institutions such as MoFA, CSIR, and development partners have emphasised the reorientation of policies, the promotion of agricultural technology adoption and the integration of smallholder farmers to markets as a means of improving their livelihoods and development. MoFA developed six strategic programmes under the Medium Term Agricultural Sector Investment Plan (METASIP I and METASIP II), with the second strategic program aimed at improving growth in incomes by increasing productivity and total production of staple and cash crops, including rice which has great potentials in northern Ghana (MoFA, 2015). In addition, despite growing emphasis on going beyond subsistence production, proportion of agricultural output sold in the output market is low in Ghana, on average about 33 percent of agricultural output is sold indicating a very low level of agricultural output commercialisation (IFAD-IFPRI, 2011). Only 10 percent of smallholders produce marketable surpluses beyond their subsistence requirements in order to participate in the output market (Siziba, Kefasi, Diagne, Fatunbi and Adekunle, 2011).

In Ghana, it has been acknowledged that there is generally little incentive for rice farmers to take steps to adopt new innovations to improve the quality of their output, as there is no price differentials (premium) based on quality at the output market (Kranjac-Berisavljevic, 2000).

Market access conditions and factor price ratios vary within smallholder farmers across regions in Ghana. Generally, smallholder farmers in northern Ghana do not participate so much in the crop output market hence have very low market share. The average marketed surplus is 15 percent in Upper East, 18 percent in Upper West and 34 percent in Northern region (IFAD-IFPRI, 2011). Smallholder farmers place premium on household consumption before market choices in staple production, but their orientation towards rice production which is a highly demanded crop need to be justified given that smallholders produce multiple crops and may have mixed orientation for different crops.

Domestic rice production covers about 40 percent of national demand (GRIB, 2012). Rice imports mainly from other countries (Thailand, USA, Taiwan, and Vietnam) helps to meet domestic demand (USAID, 2009) and the government of Ghana spends over 450 million United States dollars annually on rice imports (MoFEP, 2016). Within a decade (1993 - 2003) domestic consumption of rice increased from an annual level of less than 100,000 MT per year to over 600,000 MT (Quaye, 2007), and it is estimated that annual national rice consumption will increase to about 1.6 million MT by the year 2018 (MoFA, 2009). In Ghana, after food prices rose in the year 2008, rice imports remained a worry for policy makers (FAO, 2013). The importance of rice in the agricultural sector in Ghana's economy, for food security, and to address the problems of rising food prices and import bills raise important questions about the potentials of government policy or investment to enhance the competitiveness of rice production.

This study place emphasis on five strategic commendations by the Ministry of Food and Agriculture (MoFA) and the Council for Scientific and Industrial Research (CSIR) on improved technology bundles for rice production: improved varieties; fertiliser use; herbicide use as a land preparation and weed control method; the sawah system for water management (bunding); row planting (dibbling or drilling) among a number of recommended practises. Emphasis is also placed on farmer's market orientation in response to policies to promoting market integration.

Principally, this study intends to evaluate Agricultural Technology Adoption and Market Participation among smallholder rice farmers in northern Ghana.

1.3 Research Questions

Main: What agricultural technologies do rice farmers adopt and to what extent do they participate in the market?

Specific questions

1. What factors determine the adoption of improved rice production technologies?
2. What is the effect of using improved varieties on the yield of rice?
3. Which factors determine the level and intensity of smallholder farmer's participation in output markets?

1.4 Research Objectives

The general objective of this study is to examine agricultural technology adoption and market participation among smallholder rice farmers in Northern Ghana.

Specific objectives:

The specific objectives are to:

1. Evaluate factors that affect the adoption of improved rice production technologies.
2. Assess the effect of using improved varieties on the yield of rice.

3. Estimate the level of market participation and determine the intensity of smallholder farmer's participation in output markets.

1.5 Relevance of the study

This study contributes to existing knowledge on the factors affecting agricultural technology adoption acknowledging that there is interdependence between the decisions to adopt different rice technologies. In Ghana, several studies on factors affecting agricultural technology adoption (Zakaria, Ansah, Abdulai and Donkoh, 2016; Martey *et al.*, 2014; Bruce *et al.*, 2014), have often overlooked the joint decision of adopting improved rice production technologies together. Hence, previous studies assumed that there was no interdependence between the decisions to adopt different rice technologies. Two potential challenges with single adoption approaches is the possibility of suffering from endogeneity and simultaneity problems and providing a partial representation of farmer's real adoption choices with several technologies and inputs. Additionally, no room is made for the option of complementarity and substitutability of inputs and technologies.

This study contributes to the literature on the adoption of rice production technology in northern Ghana, by exploring the factors that determine the adoption of technologies among smallholder rice farmers in northern Ghana. Findings on the effect of improved rice varieties on yield that explain the adoption of improved released varieties among smallholder farm households will help to understand how much improved rice varieties contribute to yield.

For policy and research relevance, this study will help answer questions on how agriculture is transforming since national development policy and plans (FASDEP, METASIP, GCAP, etc.) emphasise the importance of adopting improved agricultural technology and the need to expand beyond subsistence-based smallholder system to a sector characterised by a stronger market-based orientation. The level and intensity will help unravel the line between commercially oriented, transitional and subsistence oriented smallholder rice farmers.

1.6 Organisation of the Study

The thesis is organised in five (5) main chapters. The first chapter involves an introduction, problem statement, research objectives and research questions as well as the relevance of the study. Chapter two focus on a review of relevant literate relating to the topic under study. The third chapter describes the methodology employed in the study by specifying the research design, research population and sampling design, data collection and analysis while in chapter four, the findings of the study are presented and discussed. Chapter five presents the major findings, the conclusions and policy recommendations of the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Chapter outline

This chapter of the study presents a review of literature on studies related to this topic. It presents the definition of concepts (section 2.2), technology adoption and market participation (section 2.3), determinants of technology adoption (section 2.4), determinants of output market participation (section 2.5), measurements and models employed in agricultural technology adoption (section 2.6), measurements and models employed in analysing the level and intensity of output market participation (section 2.7), summaries of studies on adoption and market participation (section 2.8) and selected rice development projects that covered northern Ghana (section 2.9).

2.2 Definitions of Concepts

2.2.1 Smallholder Farmers

Smallholder farmers are farmers who farm on small plots or acreage of land. What is considered a small plot or small acreage varies within different regions. In Ghana, the Ministry of Food and Agriculture (MoFA) defines smallholder farmers as farmers who cultivate less than 2 hectares of land. However, Chamberlin (2007) expanded the concept of smallholder to include other perspectives by categorising the definition not only on land holding size but also on wealth status, market orientation and vulnerability to risk. Smallholder farmers have limited resource endowments relative to other farmers in the agricultural sector (Dixon, Tanyeri-Abur and Wattenbach, 2004). Asuming-Brempong *et al.* (2004) suggested that the definition of smallholder farmers should not be narrowed only to land holding size but should expand to encompass different resources and risk conditions. In general, categorising smallholders based on landholdings is the most widely adopted definition of smallholder farmers.

2.2.2 Agricultural Technology Adoption

The definition of technology is not static but vary with time between different scholars. Technology is the means and procedures of bringing into being goods and services, including methods of organisation as well as physical skill or technique (Loevinsohn, Sumberg and Diagne, 2012). The preceding authors agree that new technology is new to a particular place or group of farmers, or represents a new use of skill, knowledge, equipment and or technology that is already in use within a particular dwelling or in the midst of a group of farmers. The goal of technology itself is to improve a given condition or changing the status quo to a more appropriate level. A new technology is therefore effective and or efficient compared to previous approaches of carrying out the same task. It supports the applicant of the technology to do work easier than he would have in the absence of the technology, hence it helps save time and labour (Bonabana-Wabbi, 2002).

Adoption

Adoption is defined as the mental process an individual passes from first hearing about an innovation to final adoption (Rogers, 1962). Feder, Just and Zilberman (1985), distinguished between individual (farm-level) adoption and aggregate adoption. They defined individual farmer adoption as the degree of use of new technology in long-run equilibrium when the farmer has full information about the new technology and its potential while aggregate adoption is defined as the aggregate level of use of a specific new technology within a given geographical area or a given population. Adoption can also be said to be the incorporation of a new expertise into usual practise and is generally proceeded by a period of trying and some degree of adaptation (Loevinsohn *et al.*, 2012). Adoption is in two classifications; rate of adoption and intensity of adoption. Rate of adoption is the relative speed with which farmers adopt an invention, the element of 'time' is one of its pillars. However, intensity of adoption refers to the level of use of a given technology in any time period (Bonabana-Wabbi, 2002).

The definition of technology adoption is a complex assignment since the definition keep changing with the technology being adopted. For example, Doss (2003) categorised farmers as adopters if they were using improved seeds that had been recycled for several generations from hybrid ancestors. However, in other studies farmers were categorised as adopters if they adhered to extension service recommendations of using only new certified seed (Ouma, Murithi, Mwangi, Verkuijl, Gethi, De-Groote, 2002; Bisanda, Mwangi, Verkuijl, Moshi and Anadajayasekeram, 1998). Therefore, in defining agricultural technology adoption by farmers, the primary issue to think through is whether adoption is a discrete state with dichotomous response variables or not (Doss, 2003), or the response is continuous variable (Challa, 2013). The definition of agricultural technology adoption is dichotomous (discrete) if an adopter of the technology or non-adopter take values zero and one. On the other hand, the definition is constant if the response is a continuous variable. The definition can therefore be solely a state of usage or a state of usage over time.

2.2.3 Market Participation

Scholars in the field of market participation have explained that households can participate in the market from the demand side as buyers or from the supply side as sellers (Musah, 2013; Holloway, Barrett and Ehui, 2005; Key, Sadoulet and De Janvry, 2000). Many studies have focused on the supply side of output market participation. Market participation is defined by Ana, William, Masters and Shively (2008) in terms of sales as a proportion of total harvest, for the totality of all agricultural crop output in the household which includes annuals and perennials, locally-processed and industrial crops, fruits and agro-forestry. Some authors (Cazzuffi and McKay, 2012) used market participation as a proxy for commercialisation, explaining that commercialisation can be measured in a number of ways and often understood in terms of market participation. Commercialisation of subsistence agriculture is explained as an enhanced capability to partake in the output market (Cazzuffi and McKay, 2012; Makhura, Kirsten and Delgado, 2001). To commercialise is to move from producing solely for consumption (subsistence farming) to production with a more market oriented objective (Omiti *et al.*, 2009; Pradhan, Dewina, and Minsten, 2010). Once a proportion of any agricultural output (production or harvest) is marketed, then commercialisation has taken place.

This study concentrates on the output market orientation of smallholder rice farmers. Within the output market orientation, this study further narrows down to look at smallholder farmers output market orientation for sales only and ignores output market participation for buying. This approach of measuring agricultural market participation has been used in other related studies (e.g. Musah, 2013; Kostov and Davidova, 2012; Martey *et al.*, 2012, Reyes *et al.*, 2012, Siziba *et al.*, 2011). The subsistence-commercial continuum could also be defined with regard to the participation in input markets. However, the latter is more difficult to measure and does not provide any information about output use and the output supply response which is of interest to policy makers from the point of view of food security and farm revenue.

2.3 Technology adoption and Market participation

Adoption of agricultural technologies is similarly important as participating in the market. Adoption of improved agricultural technologies by taking on of inputs is likely to influence farmers participation in the market though some studies (Melesse, 2017) suggest that adoption of improved agricultural technologies and market participation decisions are interdependent. Additionally, response from the market will vary depending on the results realised from the adoption of improved agricultural technologies, particularly yield enhancing technologies and its effect on output price depending on the nature of the market. Smallholder farmers and other agricultural related enterprises are open to more prospects and alternatives for diversifying their output via market participation to trade in their output. Improvement in crop output (either in quantity or quality or in both quality and quantity) is the knot between technology adoption and market participation. In addition to improvement in quantity and quality, adoption of improved agricultural technology can result in substantial reduction in cost of crop production making it more flexible to increase production thereby providing more opportunity to generate market surplus. Several studies (Yu *et al.*, 2011; Barrett, 2007; Diao and Hazell, 2004; Pingali, 1997; Pingali and Rosegrant, 1995) have shown that agricultural technology adoption does not only reduce poverty but also produces benefits in terms of generating output market surplus in crop production.

2.4 Determinants of Technology Adoption

Dynamic relations in the middle of physical appearance of the technology itself and the array of situations and circumstances condition farmers' decisions about whether and how to adopt new technology (Loevinsohn *et al.*, 2013).

Decisions on whether to adopt or not to adopt agricultural innovations are often the result of matching uncertain benefits and cost of adopting the new technology (Hall and Khan, 2002). Understanding the factors that influence the choice to adopt agricultural technology is important both for economists studying the determinants of adoption and the producers and promoters of agricultural technologies (Hall and Khan, 2002).

Conventionally, economic analysis of technology adoption has tried to explain adoption behaviour in relation to personal characteristics and endowments, imperfect information, risk, uncertainty, institutional constraints, input availability, and infrastructure (Uaiene, 2009; Rogers, 2003; Kohli and Singh 1998; Feder *et al.*, 1985). Recent literature has incorporated social networks and learning in the categories of factors determining adoption of technology (Uaiene, 2009).

Nonetheless, different studies tend to classify these factors into different categories. For example, Akudugu, Guo and Dadzie (2012) in their study on "Adoption of Modern Agricultural Production Technologies by Farm Households in Ghana", grouped the determinants of agricultural technology adoption into three categories namely; economic, social and institutional factors. Lavison (2013) in his study on “Factors Influencing the Adoption of Organic Fertilisers in Vegetable Production in Accra”, generally grouped factors that determine adoption of agricultural technologies into social, economic and physical categories. Many other studies (Akudugu *et al.*, 2012; Lavison, 2013) on adoption in developing countries have grouped factors that influence the adoption of technologies into various categories and this is often done to suit the designed study though individual factors are always similar.

There are no clear line separating features between variables in each type of category, though there are several categories for grouping determinants of agricultural technology adoption. Categorisation is done to suit the technology being studied, to meet the preference of the researcher among other reasons (Bonabana- Wabbi, 2002). In some instances, level of education of a farmer has been placed under the human capital category by some researchers while other authors place it under household specific factors.

This study adopts the categorisation of Mwangi and Kariuki (2015) in their study on “Factors determining adoption of new agricultural technology by smallholder farmers in developing countries”, they categorised factors determining adoption of new agricultural technology into technological factors, economic factors, institutional factors and household specific factors.

2.4.1 Technological Factors

The features of any technology plays a critical role in the adoption decision process (Mignouna, Manyong, Rusike, Mutabazi and Senkondo, 2011). Farmers' perception and understanding about the performance of new agricultural technologies significantly influences their decision to accept new innovations. A simple technology is easily understood by rural farmers and adoption is easily facilitated since farmers can operationalise the innovation with little or no challenges. Adesina and Zinnah (1993) carried out a study on "Technology characteristics, farmers' perceptions and adoption decisions" and results indicated that farmers' perception of the features of improved rice variety significantly influenced their decision to adopt improved rice technologies.

2.4.2 Economic Factors

Farm size (total farm size), crop acreage, cost of labour, off-farm income, asset value, expenditure, among others play a role in the adoption process of new agricultural technology. Farm size has been analysed by different authors as one of the important factors of agricultural technology adoption. Farm size can affect and in turn be affected by the other factors influencing adoption (Lavison, 2013). Many studies have testified both positive and negative relation between farm size and adoption of agricultural technology (Mignouna *et al.,* 2011; Uaiene *et al*., 2009; Gabre-Madhin and Hoekstra, 2007). Farmers with large acreage can afford to devote part of their land to try new technology compared with farmers with less crop acreage (Mignouna *et al.,* 2011; Uaiene *et al*., 2009).

Additionally, the adoption of new agricultural technology in the form of mechanised equipment and implements require economies of size to ensure profitability of such technologies and may not apply to smallholder farmers who cultivate small acreage. Small farm sizes positively influence adoption of agricultural technologies that are input-intensive and land saving innovations. Other studies (Mugisa-Mutetikka *et al.*, 2000; Yaron *et al.*, 1992) have reported negative, insignificant or neutral relationship between farm size and agricultural technology adoption. The cost of adopting agricultural technology (cost of labor and inputs) has been found to be a constraint to technology adoption.

Off farm income has been shown to positively influence the adoption of agricultural technology, this is so because off farm income supplements farm income and also acts as an alternative for borrowed capital in rural economies (Diiro, 2013; Reardon *et al*., 2007; Ellis and Freeman, 2004). Different authors have stated that off farm income is expected to provide farmers with liquid capital for adopting technology that comes with cost (labour and input cost) such as improved varieties, chemical fertilisers, herbicides, etc.

Diiro (2013) in a study on "Impact of Off-farm Income on Technology Adoption Intensity and Productivity: Evidence from Rural Maize Farmers in Uganda", reported a significantly positive relationship among farmers with off farm income and adoption intensity. Expenditure on purchased agricultural inputs was high among farmers with off farm income compared to farmers without off farm income. This is not to say that all agricultural technologies have shown a positive connection between off farm income and their adoption. Some studies on adoption of labour intensive technologies have rather shown a negative connection between off farm income and agricultural technology adoption. Goodwin and Mishra (2002), explained that the quest of farmers to be engage in off farm activities and earn income will decrease the number of household labour involved in farming and this may undercut their adoption of contemporary labour intensive agricultural technologies.

2.4.3 Institutional Factors

Smallholder farmers within a social group easily share their agricultural experience with other members and learn from each other the benefits and usage of new agricultural technologies they have come into contact with. Uaiene *et al*. (2009) advocates that institutional factors in the form of social networks and groups are essential for individual decisions, and that, in the particular context of agricultural innovations, farmers share information and easily pick up from each other. Conley and Udry (2003) modeled the adoption of pineapple production practises in Ghana and found that social learning is important in the spread of the new technologies. Katungi and Akankwasa (2010), found that farmers who engaged more in community or farmer-based organisations were more likely to take part in social learning about agricultural technology and therefore are most likely to adopt agricultural innovations.

Access to information regarding a new agricultural technology is another factor that influence adoption. Acquisition of information about new agricultural technology via extension services, training and demonstrations by agricultural research institutions and projects enables farmers to learn the existence as well as the effective use of innovations. Extension agent act as a link between the innovators (researchers) of the technology and users (farmers) of that technology (Mwangi and Kariuki, 2015). Farmers are rational and will only adopt a technology they are aware of or have heard about. Full information about an innovation reduces uncertainty about the performance of that innovation hence, may change the individual's assessment of purely subjective to objective over time (Bonabana-Wabbi, 2002).

A lot of authors have reported a positive relationship between extension services and technology adoption. A good example includes; Adoption of modern agricultural technologies in Ghana (Akudugu *et al.*, 2012); Adoption of Imazapyr-Resistant Maize Technologies (Mignouna *et al*., 2011) just to mention a few. Other authors (Bonabana-Wabbi, 2002 ; Yaron, Dinar and Voet, 1992) have stated that the influence of agricultural extension agents can counter balance the negative effect of lack of years of formal education in the choice that farmers make to adopt agricultural innovations. That's informal education via training and practical demonstration facilitates understanding and up take of agricultural innovations even if the level of education is observed as low among farmers.

Credit access is another institutional factor that encourage smallholder farmers to adopt agricultural technology. It is believed that credit access promotes the adoption of risky and capital intensive technologies through relaxation of the liquidity constraint of inadequate finance (Simtowe and Zeller, 2006). On the other hand, credit access in some countries is gender biased against females and as such females are unable to finance yield-raising technologies, leading to low adoption rates (Muzari, Gatsi and Muvhunzi, 2012).

2.4.4 Household Specific Factors

Farmer specific factors (education, age, gender, household head) and household specific factors (Household size, number of active members, asset value, land holdings, etc.) have influence on the adoption of agricultural technology. Conventional and current research have often viewed the status of a farmer as a household head to be a positive stand towards adoption of innovations. Early studies (Hammond, 1966) and later (Theis, Lefore, Meinzen-Dick and Bryan, 2018; Kassie, Marenya, Tessema, Jaleta, Zeng, Erenstein and Rahut, 2018; Tarekegn, Haji and Tegegne, 2017; Asfaw, Di Battista and Lipper, 2016) have captured the status of a farmer as household head by explaining its importance in relation to social norms and decision making in extended families over input and resources use which is common in developing countries particularly among smallholder farm households. Therefore, being a household head places you in a better position in making decisions about agricultural production in the household compared with other members.

Farmer's education has been assumed to have a positive effect on farmers' choice to adopt new agricultural technology. Farmer's ability to obtain, process and use information relevant to adoption of a new agricultural technology is improved if a farmer has attained some level of education (Lavison 2013; Mignouna *et al.*, 2011; Namara, Weligamage and Barker, 2003).

Higher educational attainment influences respondents' attitude and thoughts making them more open, rational and able to analyse the benefits of the new technology (Waller, Hoy, Henderson, Stinner and Welty, 1998), this facilitates the introduction of new agricultural technology which eventually influence the adoption process (Adebiyi and Okunlola, 2010).

Yet, some studies have testified negative influence of education on the rate of agricultural technology adoption (Samiee, Rezvanfar and Faham, 2009; Banerjee, *et al*., 2008).

Though generally, educational attainment positively influence adoption, a study by Uematsu and Mishra (2010) titled "Can Education be a barrier to Technology Adoption?" reported a negative influence of formal education on adopting genetically modified crops. This further affirms the fact that higher educational attainment improves farmers understanding and access to information on innovations and are therefore able to make balanced judgements.

In terms of gender, most studies have stated varied confirmations concerning the different roles men and women play in technology adoption (Bonabana-Wabbi, 2002), though gender issues in agricultural technology adoption have been studied extensively. In Ghana, earlier studies on the effect of gender on agricultural technology adoption was undertaken by Morris and Doss (1999), they found no significant relationship between gender and likelihood to adopt improved maize. They concluded that if in a particular context men tend to have better access to productive resources (access to land, labour, credit, etc.) that influence adoption than women, then technology adoption will be tailored towards a particular gender. Explanations are that being male or female does not primarily determine adoption of innovations but differences in roles, opportunities, decision making and control over productive agricultural resources within male and female is often the underlying course that influence adoption among males and females.

In terms of age, it is usually expected that older farmers have more experience, but this may be counteracted by younger farmers being more innovative (Doss, 2003). Farming experience is a bit more difficult to measure, and it is important to define exactly what farming experience entails: is it all farming experience? Experience farming one's own plot? Experience farming a particular plot? Experience farming a particular crop? Given the age of farmers, difference may exist depending on how experience is captured.

Household size have often been viewed as a reflection of labour supply for agricultural activities and the household's ability to supply surplus labour to non-farm activities and income that is received could be invested into farm activities (Gautam and Andersen, 2016). However, the proportion of dependents or active members may mare this assumption and produce mixed results if not measured well.

2.5 Determinants of Output Market participation

The choice of smallholder farmers participation in the output markets is determined by many household (micro) and macro level factors (Gebreselassie and Ludi, 2008). Both internal factors that are within the control of farm households and external factors influence farmer's participation decisions. Internal and external factors may perhaps have negative or positive effect on crop output marketing.

2.5.1 Internal Factors

Demographic factors such as age, sex, marital status of farm household heads have an effect on output market participation. Age of the household head may pose a dual directional effect on output market participation. Ehui, Benin and Paulos (2009) explained that older household heads tend to have more dependents as household members causing more consumption compared with younger household heads, hence lowering marketable surplus. Also, older household heads may have built relationship with partners over time and are therefore more likely to easily get access to resources like credit and land (Adegbola and Gardebroek, 2007). Though sex does not directly influence market participation, gender roles, social and economic activities that are geared towards the sex of household heads affects output market participation. Male headed farm households compared with their counterpart female headed households are expected to have a positive impact on output market participation because males are often more resource endowed than their counterpart female. Additionally, female headed household heads are more likely to be resource constrained in terms of access and control of land, household labour, agricultural production decisions among others, hence affecting female headed household heads ability to generate marketable surplus (Guiterrez, 2003).

Human capital, which comprises education, experience, skills, training and capabilities has a positive effect on output market participation. This is because farm households human capital development, enhance their ability to utilize market information, which may in turn reduce marketing cost and make it more profitable to participate in the market (Mwangi and Kariuki, 2015; Siziba *et al.*, 2011). The number of household members (Household size) is often used to explain the supply of cheap family labour for crop production and is expected to positively influence output market participation. However, a larger household number (size) alone is not a sufficient condition, but the proportion of active members within the households measures availability of family labour compared with larger household members constituted by a greater proportion of dependents.

Ownership of communication equipment's (radio sets, television sets, mobile phone devices, etc.) helps in facilitating marketing via dissemination of marketing information to smallholder farmers which have a positive effect on output market participation (Zamasiya, Mango, Nyikahadzoi and Siziba, 2014; Siziba, 2014; Musah, 2013). Availability of timely market information through these communication channels will boost the confidence of farm households who are willing to participate in the output market. In addition, ownership of transport and farm equipment's such as motorcycles, trucks, tractors and tractor implements have a positive influence on output market participation by reducing the cost of production and the cost of transporting farm output from the farm to the market (Key, Sadoulet and De Janvry, 2000).

Egbetokun and Omonona (2012), found that the major determining factors influencing farmer's participation in the output market are age, marital status, labour, farming experience and farm size. Onoja *et al.* (2012) explained that the probability of participating in the output market depends on household size, distance to the nearest marketing channel, price of the commodity and sex of the farm household head. Pender and Alemu (2007) showed that increasing production of food crops is the most important factor contributing to increased output market participation and that improvement in smallholder farm household's access to roads, production land, livestock, farm equipment, and market connectivity are key to facilitating improved smallholder output production and market participation.

2.5.2 External Factors

External factors that influence output market participation spans from global scale drivers like trade liberalisation, changes in development policy and globalisation (associated with rapid growth of world trade, internationalisation of products, reduced transport and communication costs, changing world food system, etc.) are the driving forces behind the changing nature of demand for agricultural output (Todaro and Smith, 2011; Hazell, 2011; Von Braun and Díaz-Bonilla, 2008). Economic development within a country leads to structural transformation, improved per capita income, rising consumption expenditure and increased incomes which initiates increased demand for food (agricultural output), (Hazell and Wood, 2008; Pingali, 2007). At the country level, general growth in population, demographic changes, development of non-farm sector (market infrastructure and related institutions that provide market information), land tenure, urbanisation and consumption preferences are potential external factors that affects output market participation (Sigei, Bett and Kibet, 2014).

Institutional factors like access to extension service, training and availability of market infrastructure have an influence on market output participation. Poor market infrastructure like market centres and roads have a negative effect on market participation. A negative effect is expected because the majority of smallholder farmers in developing countries are located in remote areas with poor infrastructure and often fail to participate in the output market due to high transaction cost (travel to market centers) involved (Makhura *et al*., 2001; Key *et al*., 2000; Goetz, 1992). Access to training and extension service is expected to exert a positive effect on market participation because it is through extension services that farmers are exposed to improved production technologies and good agricultural practices, and are able to develop skills and acquire knowledge on output marketing.

Price of output is determined by market forces and not under the control of farm households. Improvement in the selling price of crop output positively influences smallholder farm household's output market participation. In line with the law of demand, improvement in the price of crop output provides an incentive for smallholder producers to supply more to the output market (Alene *et al*., 2008).

Review of literature from other related studies indicate that output price, yield, place of sale, distance to market, farm size, number of crop plots, ownership of radio and mobile phone, total asset value, access to extension and training on crop production, age of household head, education of household head, household size, proportion of active members, household expenditure, remittance, decision on amount to keep and sell among others have been observed to significantly influence smallholder farmers participation in output markets (Mulisa, 2017; Mignouna *et al.*, 2015; Bruce *et al.*, 2014; Musah, 2013; Kostov and Davidova, 2012; Martey *et al.*, 2012; Olwande and Mathenge, 2011; Mather *et al*., 2011; Komarek, 2010; Alene *et al.*, 2008; Barret, 2007).

2.6 Measurements and Models employed in Agricultural Technology Adoption

Modelling technology adoption is often dependent on how adoption is measured. In most adoption studies (Martey *et al.*, 2014; Bruce *et al.*, 2014), the measurement of adoption is often discrete and the type of model is dependent on the number of outcomes observed for the dependent variable (adoption). A binary probit or logit model is often employed in situations where the number of outcomes are two. The probit model follows a cumulative standard normal distribution whereas the logit model follows a cumulative standard logistic distribution. The choice between probit and logit is therefore based on the distribution function of the error term, which can either be standard logistic or standard normal (Verbeek, 2010). The estimation procedure applied for calculating parameters of non-linear models like probit and logit is by Maximum Likelihood. Linear probability model is also applicable in analysing binary choice. In Linear probability model, a linear regression model (OLS) is applied to a limited dependent variable (dummy), hence the procedure is straight forward. The challenge with Linear probability model is that the error terms are not normally distributed and some predicted values of the probabilities are smaller than zero whiles others are larger than one (Stock and Watson, 2012; Greene, 2012).

However, in cases where the number of outcomes observed are more than two, the choice of a model is dependent on whether the outcomes are ordered or not ordered. A multinomial logit or probit is often estimated to assess adoption where there is no ordering of outcomes whiles an ordered probit or logit is employed in cases where the outcomes are ordered (logical ordering of technology alternatives), (Asteriou and Hall, 2007; Johnston, 1991). If adoption is measured based on count outcomes (number of technologies) then a Poisson regression model is applied. The nature of the Poisson distribution is conditioned on the principle of equidispersion (condition where the mean is equal to the variance) and this restricts the Poisson distribution (Greene, 2012). In other alternative models (eg. Negative binomial models), the equality of the conditional mean and variance which restricts the Poisson distribution have been rejected to allow for over-dispersion (variance is larger than mean) and under-dispersion (variance is lower than mean), (Stock and Watson, 2012).

In terms of measuring multiple adoption decisions together, most univariate models (Probit, Logit, etc.) employed have often overlooked the joint decision of adopting multiple production technologies together and hence, assumed that there is no interdependence between the decisions to adopt different production technologies. Two potential challenges with single adoption approaches is the possibility of suffering from endogeneity and simultaneity problems and providing a partial representation of farmer's real adoption choices with several technologies and inputs. These univariate approaches place little emphasis on the complex nature of adoption in the face of complementarities between technologies by focusing on only single input or technology adoption decisions. Additionally, no room is made for the option of complementarity and substitutability of inputs and technologies.

An extension of the univariate probit models used for estimating adoption is the multivariate probit model. The multivariate probit model makes it possible to estimate several probit models simultaneously, while allowing the error terms in the individual models to be correlated (Greene, 2012). The multivariate probit model estimates several correlated dichotomous outcomes together because it simultaneously capture the impact of the set of covariates (explanatory variables) on each of the technology options, at the same time allowing for possible relationships among unobserved disturbances, as well as the relationships between the decisions to adopt different technologies (Greene, 2012). Correlation results from multivariate probit model makes it possible to ascertain complementarity and substitutability between multiple technologies that farmer's face (Asfaw *et al.*, 2016; Ndiritu *et al.*, 2014), compared with univariate approaches.

2.7 Measurements and Models employed in analsing the level and intensity of output Market Participation

In analysing participation and intensity of output market participation, there is the need to take into consideration the endogeneity of participation decisions and intensity of participation (how much to participate with). Smallholder farmers choice of participation and intensity of participation in the output market is not randomly assigned, the decision on participation (whether to participate or not to participate) and intensity of participation (how much to participate with) in the output market is under the control of the farmer. Analysing participation and intensity of participation faces the problem of self-selection bias given that output marketing decisions (decision to sell and how much to sell) is under the control of the farmer. Smallholder farmers differ in terms of many factors (Wealth, access to various services, etc.), both observed and unobserved factors which influence participation and intensity of participation. Therefore, market participation and intensity of participation can be potentially endogenous. There is the need to account for this potential selection bias when analysing participation and intensity of participation to avoid generating inconsistent estimates from results.

Different econometric procedures have been modeled to correct for the potential problem of self-selection bias. In general, sample selection model (Siziba *et al.*, 2011; Alene *et al.*, 2008; Goetz, 1992), switching regression model (Bwalya *et al.*, 2013; Vance and Geoghegan, 2004) and double hurdle or two-tier model (Reyes *et al.*, 2012; Olwande and Mathenge, 2012) are common two step approaches that are often adopted. Two step approaches assume that market participation is composed of two decision procedure (Olwande and Mathenge, 2012; Barrett, 2007), the first which is the decision to participate or not to participate in the output market and the second which is how much output to participate with if a given household decides to participate in the first stage. Sample selection model, switching regression model and double hurdle model takes these two steps into consideration. Nevertheless, some studies (Martey *et al.*, 2012; Omiti *et al.*, 2009; Newman *et al*., 2003) that concentrate on the second decision process often adopt the use of a Tobit model which considers only a one step procedure.

The traditional approach is the application of the one step Tobit model which does not consider the first decision making choice as to whether to participate or not to participate in the output market (Decision to sell or not to sell crop output). The assumptions of the Tobit model (Tobin, 1958) is that the probability of participating in the market (decision to sell) and the intensity of participation (how much to sell) is influenced by the same set of factors (Wan and Hu, 2012). In the Tobit model approach, all farm households including those households who did not participate in the output market (Censored zeros) are involved in the analysis without taking into consideration the source of the zeros. The Tobit model treats farm households that recorded zeros as if they did not sell because they did not want to, but in contrast they may have not sold because there was no market. However, Newman *et al.* (2003) explained that all zeros recorded as a result of non-participation choice of farm households may be due to differences in access to marketing information, institutional services, socioeconomic factors, demographic factors among other factors. The Tobit model assumes that the two stage decision procedure by farm households given the decision to participate and how much output to participate with is taken as same. The Tobit model is suitable in cases where the decision to participate (sell) and the intensity of participation (quantity sold) are made at the same time.

Switching regression is a two-step procedure model that permits variables to influence the two decisions (decision to sell and how much to sell) in different directions (Alene *et al.*, 2008). The switching regression procedure is modeled to understand characteristics that influence farm households who do not participate in the output market (those with the zero values). Switching regression approach can be used to account for the self-selection bias of participation and intensity of participation (Guo and Fraser, 2014; Van and Geoghegan, 2004). A double-huddle model is suitable under conditions where decisions are not jointly made (Mather *et al*., 2011). The double-huddle model is a two-step estimation procedure where a probit model is estimated in the first step to determine the probability of participating in the output market and a truncated model is used to assess the factors influencing the intensity of output participation in the second step. The disadvantage of the double-huddle model arises in cases where some farm households in the sample did not participate in the market (sell). In such situations the double-huddle model is prone to selection bias problem due to its failure to account for the selection bias and therefore yields biased and inconsistent estimates (Winship and Mare, 1992).

The Heckman sample selection model is another two step approach introduced by Heckman (1979). Heckman two step approach consist of two equations and it is estimated using a probit regression model in the first stage to predict the probabilities of participating in the output market. The second step is estimated by employing the Ordinary Least Square (OLS). An Inverse Mills Ratio (IMR) is generated in the first stage and included as an additional regressor in the OLS. Wooldridge (2006) suggested that the second stage model (OLS) should include some additional factors (variables) as exclusion restriction variables (to perform the role of an instrumental variable). The Heckman two step procedure addresses the problem of selection bias that arises due to self-selection. Inclusion of the IMR in the second step helps to ascertain whether the unobservables that influence intensity (how much output to participate with) tend to occur with unobservables that affect decision to participate based on the association between the error terms in the intensity model (OLS or second step) and the participation model (Probit or first step).

2.8 Summaries of studies on Adoption and Market Participation

Improvement in agricultural technology adoption among smallholder households has the ability to propel their output beyond household consumption creating enough surplus to earn additional income via output market participation. A number of empirical studies have focused on smallholder adoption and participation. Zakaria *et al.* (2016) assessed the determinants and effects of JICA rice technology adoption in the northern region of Ghana.

The objective of the study was to analyse the adoption of JICA rice production technologies and its effect on output in Sagnarigu municipality of the Northern Region. A sample size of 120 farmers were randomly selected from six communities and interviewed via a questionnaire. Determinants of the adoption of the JICA rice production technologies was analysed using a logistic model and the propensity score matching method was employed to ascertain the effect of adoption on rice output. Adoption of JICA rice production technologies was positively influenced by fertilizer subsidy and farmer based association and negatively influenced by use of other improved seeds, farm size, household size and access to extension. Adoption of JICA rice production technologies was found to significantly improve rice output. The study recommend that government programmes should support farmers to improve upon their adoption of rice production technologies.

Wiredu, Zeller and Diagne (2015) also evaluated the determinants of fertilizer adoption among rice producing households in northern Ghana. The objective of the study was to determine factors that influence the adoption of fertilizer and fertilizer combination among rice producing households. A total sample of 820 rice producing households were chosen at random from 82 communities in developed rice valleys in northern Ghana. Factors affecting the probability and intensity of adoption was assessed by using the Crag's two-step regression models. Yield expectation and household participation in fertilizer subsidy program were the two principal factors that significantly influenced adoption. Other factors like harrowing of fields, good agricultural practices and drilling of seeds also determined adoption of fertilizer. They suggested that enhancing access to agricultural technology information will expose the benefits of adopting fertilizer, fertilizer combinations and complementary technologies such as improved seeds to rice farm households.

Asante *et al.* (2014) assessed NERICA rice adoption and its impact on technical efficiency of rice producing households in Ghana. The objective of this study was to evaluate the Multi-national NERICA Rice Dissemination Project (MNRDP) that disseminated rice production technologies to promote the New Rice for Africa (NERICA) varieties together with complementary agronomic technologies in Ghana. The study used a cross sectional data from three regions in Ghana. A total of 200 rice producing households were systematically and randomly selected from 20 communities in three districts in southern and northern Ghana (Ejura-Sekyeredumase, Hohoe and Tolon-Kumbungu) where the project was implemented. They employed the counterfactual outcome framework by adopting the Cobb-Douglas production function to estimate efficiency scores and the average treatment effect (ATE) to evaluate the impact of adoption of the NERICA varieties on technical efficiency. Adoption of NERICA varieties was revealed to have a positive impact on technical efficiency of rice producing households. Extension services from institutions and NGOs positively impact technical efficiency. They recommended that provision of training should still be promoted to enhance adoption of improved varieties since adoption is key in improving technical efficiency and to strengthen the relationship between farmers, institutions and NGO's.

Bruce, Donkoh and Ayamga (2014) assessed the adoption of improved rice varieties and its effect on farmers output in Ghana. The objective of the study was to investigate factors that affect improved rice variety adoption and its effect on output by employing the use of a treatment model comprising a production function and a probit equation. Their results revealed that farm size, labour and fertiliser had a positive and significant impact on rice output. Additionally, formal education, household size, farm size and extension service influence the likelihood of adopting improved varieties. They recommended that rice farmers form groups to support one another, improvement in the fertiliser subsidy program and expansion of opportunities to improve farmers' literacy.

Ragasa *et al.* (2013) evaluated the Patterns of Adoption of Improved Rice Technologies in Ghana. The study collected nationwide data on the patterns of adoption of improved technologies with the goal of assessing the progress of the National Rice Development Strategy (NRDS) and identifying entry points for strengthening the implementation of the program. Data from a survey of 576 rice farmers in 23 districts in 10 regions in Ghana implemented by CRI, SARI and IFPRI. The study employed a three-stage, clustered, and randomized sampling procedure. The study covered upland and lowland systems, rain fed and irrigated covering four major agro ecological zones: forest, transitional, northern savannah, and coastal savannah. The study concentrated on six key recommendations by CSIR and MOFA on technological packages for rice: improved varieties, fertilizer use, herbicide use, the sawah system (bunding, puddling and leveling), planting method and seed priming. The study revealed that adoption of modern varieties was generally low compared with other estimates. With very high adoption rates in irrigated areas compared with lowland rain fed and upland areas with Northern Savannah zone recording the lowest adoption rate due to continual use of traditional varieties. Fertilizer adoption was high and attributed to the fertilizer subsidy program. Fertilizer adoption was very high in irrigated areas and lowest in the Northern Savannah and Forest zones. Adoption of the sawah system (bunding, puddling, and leveling) was limited in general but above average in irrigated areas and poorly practiced in lowland rain fed areas. Planting in rows was very low across areas except for irrigated. Herbicide application was generally high but significantly low in the upper regions in the Northern Savannah compared with the Forest and Transitional zones. A greater proportion of farmers generally participated in the market. Northern Savannah zone recoded the lowest participation rate. They recommended greater education and training on rice technologies and on safe handling of herbicides, and getting timely and more cost effective mechanisation services to many parts of Ghana.

Martey (2014) undertook a study on market information and agricultural commercialisation to analyse the effect of the different types of access to market information on the extent of agricultural commercialisation among smallholder farmers in Ghana. A structured questionnaire was used to gather information from 150 smallholders via a multi-stage systematic sampling technique. A truncated regression model was employed to estimate the impact of market information on extent of agricultural commercialisation. The results revealed that market information, education, access to land, farm size, gender, number of male adults within the household and non-farm income significantly influenced the extent of agricultural commercialisation among smallholder farmers. The study concluded that access to market information from informal sources, such as friends, relatives and farmer association significantly influence the extent of agricultural commercialisation. The study recommended that agricultural development projects should strengthen the delivery of the informal market systems.

Musah (2013), carried out a study on market participation of smallholder farmers in Ghana. The objective of the study was to evaluate the levels of market participation, the intensity of participation and constraints to marketing by smallholder maize and groundnut farmers. 400 maize and groundnut farmers were randomly sampled through a multistage sampling procedure from four agricultural districts in the region. Market participation was calculated using the household commercialisation index. A double hurdle model was employed to estimate the factors influencing participation and intensity of market participation. Constraints to output marketing was ranked by employing the Garrett ranking technique. The results showed that output commercialisation was low and moderate for maize and groundnut respectively. The probability and intensity of output market participation was influenced by farmer characteristics (gender, household size, age, education); public and private assets factors (extension contact, price, credit, farm size, output, and experience) and transaction cost factors (place of sale and market information). Unfavourable market prices was ranked as the topmost constraints and lack of government policy on marketing as the least constraint to marketing. The study concluded that maize is produced as a staple while groundnut is produced as a cash crop. The study recommended that government should institute productivity enhancing measures to increase the productivity and marketable surplus of farm households, address credit needs of smallholders and to improve agricultural market information delivery service.

Martey, Alhassan and Kuwornu (2012) assessed the commercialisation of smallholder agriculture in Ghana. The focus of the study was to examine the trends in crop production by stallholders in Ghana and to estimate the level of commercialisation. The study concentrated on maize and cassava production. 250 smallholder farmers from twelve farming communities in the Effutu Municipality in Ghana were selected at random. The Tobit regression model was used to estimate factors that determine the intensity of commercialisation. The study concluded that price of output, extension access, farm size, distance to market and market information influenced the intensity of commercialisation. These results have implications for agricultural policy in Ghana. They recommended that road network from farms to markets be upgraded, investment in the expansion of retail outlets in farming areas to lower transportation costs and encourage rural farmers to trade in high-value commodities.

2.9 Selected rice development projects that covered northern Ghana

In table 2.1, some selected rice projects that covered northern Ghana prior to the survey for this study have been presented. The table presents the project name, project duration, funding agency and estimated budget allocations. These development interventions focused on rice sector policies, infrastructure, research, credit, marketing in addition to dissemination of improved rice production and postharvest technologies across districts in northern Ghana.

Table 2.1: List of Projects and Programmes to Support Rice Sector in Northern Ghana

Project Name	Project Duration		Funding Agency / Donors	Estimated Budget Allocations
	Year started	Year ended		
Food Security and Rice Producers Organisation Project	2000	2008	AFD (France)	USD 1.8 million
Special Programme for Food Security in Ghana	2002	2007	FAO	USD 1.26 million
Food Security and Rice Producers Organisation Project	2003	2008	AFD (France)	USD 1.8 million
Dissemination of Improved Rice Production Systems with Emphasis on NERICA to Reduce Food Deficit and Improve Farmers Income in Ghana	2004	2006	FAO, UNIDO, Japan govt.	USD 970,415
Project for Promotion of Farmers' Participation in Irrigation Management	2004	2006	JICA	USD 2.52 million
NERICA Rice Dissemination Project	2005	2010	AfDB/ Ghana govt.	USD 4.57 million
The Study of the Promotion of Domestic Rice in the Republic of Ghana	2006	2008	JICA	USD 1.62 million
Improvement of Drought Tolerance of Rice through Within-Species Gene Transfer	2007	2009	AGRA	USD 35, 000
Rice Seed Production project	2008	2010	AGRA	USD 149,973
An Emergency Initiative to Boost Rice Production	2008	2010	USAID	USD 1.27 million
Ghana Rice Interprofessional Body (GRIB)	2008	2012	AFD (France)	USD 140,000
Rice Sector Support Project	2008	2014	AFD (France)	USD 17.3 million
Project for Sustainable Development of Rainfed Lowland Rice Production	2009	2014	JICA	USD 3.6 million
Improving Yield, Quality and Adaptability of Upland and Rain fed Lowland Rice Varieties in Ghana to Reduce Dependency on Imported Rice	2011	2014	AGRA	-
Market Development (MADE) programme in Northern Ghana	2013	On-going	DFID – UKAID	USD 19 million
Agriculture Technology Transfer project	2013	On-going	USAID	-
System of Rice Intensification (SRI)	2015	-	World Bank	USD 1 million

Source: Compiled from various sources.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Chapter outline

This section outlines the methodology employed in the study. It presents a description of the study area (section 3.2), the research design (section 3.3), the data sources and sampling techniques (section 3.4) and the data analysis and presentation methods (section 3.5).

3.2 Study area

The study covered smallholder farmers in northern Ghana consisting of Northern, Upper East and Upper West regions. These three regions are among the poorest and least developed regions of Ghana. In general, the mainstay of the people in the three regions is agriculture hence the majority of the economically active group in northern Ghana are engaged in agriculture (GSS, 2012). They are largely subsistence food crop producers with most of the populace living in rural areas. The major crops grown are maize, rice, millet, sorghum, yam, groundnut, cowpea and soybeans (MoFA, 2016). Geographically the three regions share borders with the Republic of Togo to the east, Ivory Coast to the west and Burkina Faso to the north. Within the country, northern Ghana is bordered by the Volta region on the south east and Brong-Ahafo region on the south west. The three regions cover a total land area of 95,000 km² with an estimated population of 4,228,116 (GSS, 2012).

Northern Ghana is mainly drained by the black and white Volta Rivers and their tributaries. The climate in northern Ghana is relatively dry, with a single rainy season that begins in May and ends in October. The amount of rainfall recorded annually varies between 750 millimeters and 1,050 millimeters. The dry season starts in November and ends in March/April with high temperatures of about 38 degrees Celsius on average occurring towards the end of the dry season (World Weather and Climate Information, 2018). Northern Ghana is located mainly within the guinea savannah vegetation characterised largely by drought-resistant grasses, intermixed with savannah woodland.

Northern Ghana plays a key role in agriculture with large hectares of suitable agricultural land and is considered as the bread basket zone of the country. Most smallholder farmers in these regions have benefited from a lot of agricultural development projects aimed at increasing productivity and improving livelihoods. Different projects over the years have introduced farmers to different innovations to improve their productivity. However, farmers still face a lot of challenges in their production activities. Marketing of farm produce is one of the major problems facing farmers in northern Ghana. Farmers in most rural areas are compelled to sell their produce at farm-gate prices because of the lack of access to market centers. Twenty two (22) districts were selected for the study. These include ten (10) districts in Northern region (Chereponi, Karaga, Tolon, Sawla-Tuna-Kalba, West Mamprusi, Yendi, kpandai, Savelugu and East Gonja), Six (6) in Upper East region (Bawku municipal, Bawku West, Binduri, Garu Tempani, Kasena Nankana and Bongo) and Six (6) in Upper West region (Nadowli-Kaleo, Wa East, Wa West, Jirapa, Sissala East and Wa Municipal).The selected districts are colored in Figure 3.1 below.

Map of Selected Districts

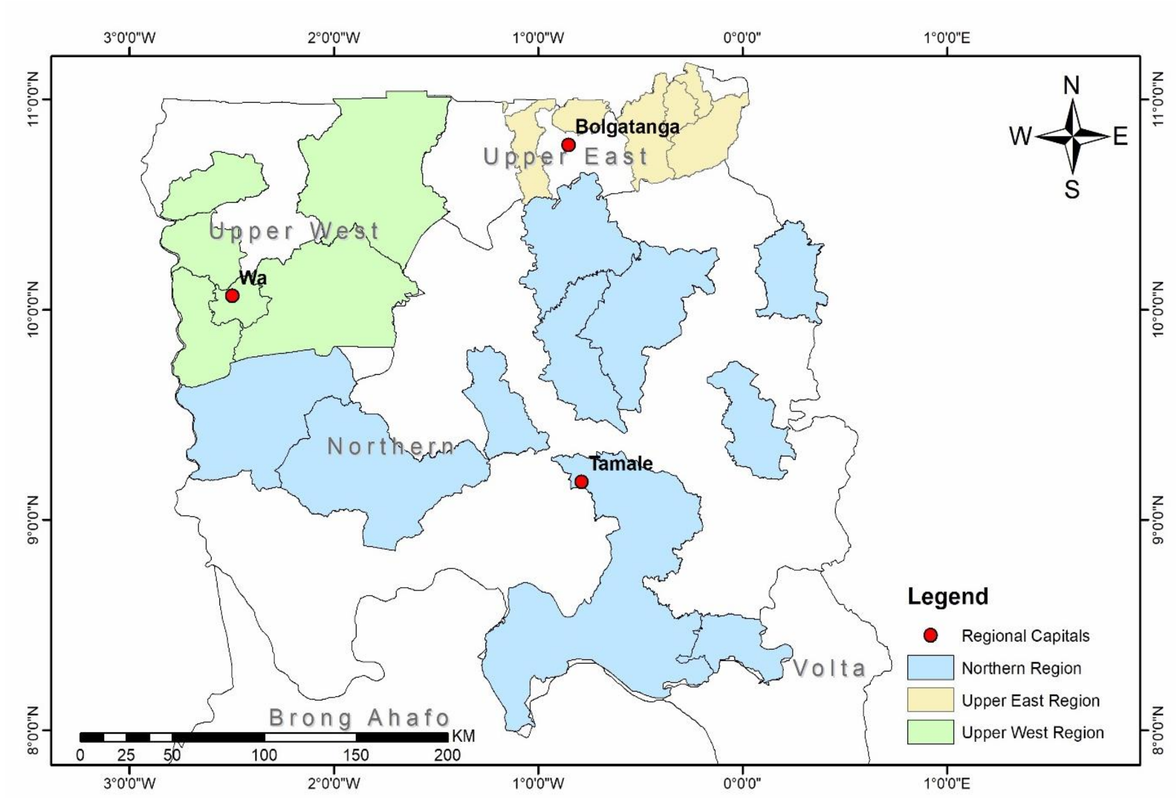


Figure 3. 1: Map of selected districts

3.3 Research design

The study used secondary data from cross-sectional household survey undertaken by SARI. Data on sampled smallholder rice farmers in northern Ghana in the year 2015 was extracted and it contained the rice production practices and output information. Secondary data was obtained because the data suitably captured information on adoption of rice production technologies and output distribution among smallholder rice farmers in northern Ghana, and consequently provided enough data to meet the objectives of the study.

3.4 Data

3.4.1 Sources of data

As indicated earlier, the data used for the present study sourced from the socioeconomic division of the Savanna Agricultural Research Institute (SARI), a subsidiary of the Council for Scientific and Industrial Research Institute (CSIR) in Ghana. The study used a sample of rice farmers from northern Ghana who were involved in the USAID GENDER, CLIMATE AND ADOPTION (RICE/SOYBEAN/MAIZE) SURVEY in the year 2015.This was a collaborative work between SARI and USAID under the USAID-SARI Direct Support Project. The survey was focused on agricultural households in three regions (Northern, Upper East and Upper West). A stratified, multistage cluster sampling technique was used for the survey. The survey was conducted in November 2015 to December 2015 through face-to-face interviews which took place in respondents' houses. Farmers were not given incentives to participate. All farmers who were approached agreed to participate but not all of them answered all the questions.

The survey questions were related to two periods. First, the preceding full calendar year of 2015 for which detailed information on rice production was required and second, other years preceding 2015 for which less detailed information was collected. The focus of the survey was to study agricultural households that were involved in the production of Maize, Rice and/or Soybean. Additionally, only households that reported being engaged in the production of any of these crops in 2015 were included in the sample. The survey instrument was designed in such a way that both quantitative and qualitative information were collected. The data captured information on: household member's demographics, time allocation and income sources, inputs and outputs, plot characteristics, land and nonland assets, land tenure and land holdings, decision making, labour use (family and hired labour), crop production technologies, non-labour income, remittance, credit, crop sales, distribution of output, extension and training, consumption and expenditure, etc.

This study used information of farmers that were engaged in rice production. Focus was placed on the section that captured distribution of output (crop sales) and adoption of rice production technologies (use of herbicides, bunding around plots, dibbling in line/ drilling, use of improved varieties, fertilizer use, application of manure). Other sections of the data that captured household demographics and assets, extension and training, consumption and expenditure, etc. were used as explanatory variables.

3.4.2 Sampling

Based on the data obtained, the dependent variables for the empirical analysis were created to inform the beginning of sampling rice farmers for the analysis. The creation of the dependent variables (technologies adopted, yield per acre and proportion of output sold) entailed careful calculations. In categorising farmers' rice varieties into improved and non-improved varieties; all farmers who could identify the names of rice varieties that they cultivated were retained in the sample and based on the names of the varieties cultivated farmers were grouped into two, farmers who adopted improved varieties and farmers who used non-improved varieties. Yield per acre was calculated for each plot/ field of rice cultivated by farmers. Farmers with yield exceeding the potential attainable yield pegged at 6 - 8 MT/ha (MoFA, 2016) were excluded. The proportion of rice output sold was also computed. Total quantity sold was expressed as a percentage of total quantity harvested.

Whenever the calculation of this proportion was not possible respondents were removed. Farmers for which quantity sold was missing and farmers for which the distribution of output did not add up to total output (harvest) were also excluded.

Furthermore, respondents for which some values on explanatory variables were missing were also left out (meaning that a household reported producing rice, but some data were missing and other values reported wrongly making it impossible to calculate the corresponding values of variables). Other explanatory variables were excluded mainly due to many missing values. These procedures decreased the original 506 household level information to 429 households. Calculations and categorizations of all dependent variables was possible for the 429 households. Additionally, these households had information for all independent variables and constituted the final sample used for the analysis of the study objectives.

3.5 Data analysis and presentation methods

Stata software was used for the analysis of the three objectives as well as carrying out descriptive statistical analysis to support the results of the study. The results from the analysis are presented in graphical and tabular forms in chapter four.

3.5.1 Theoretical Framework of Adoption and Market Participation

Rogers and Shoemaker (1971) defined adoption as the decision to apply an innovation and to continue using it. Market participation is defined by Ana, William, Masters and Shively (2008) in terms of sales as a proportion of total harvest, for the totality of crop output in the household. The theoretical framework treats technology adopters and market participants as rational households (farmers) who make choices in their own best interest.

Rice producing households (farmers) are expected to maximize their utility function in the presence of constraints that influence their adoption of technologies and participation in output markets (Asfaw *et al.*, 2012). The difference between the utility from adopting any rice technology or participating in the output market is denoted by (U_{iA}) and the utility from not adopting any rice technology or not participating is given as (U_{iN}). The net utility of both may be denoted as U_i*, such that a utility maximizing household, *i*, will choose to adopt any rice technology or participate in the output market if and only if the utility gained from adopting or participating is greater than the utility from not adopting or not participating ($U_i* = U_{iA} - U_{iN} > 0$). Utilities of rice producing households are not observable but can be represented as a function of observable elements in the latent variable model below (equation 3.1). Technology adoption and market participation decisions of rice producing households can be modeled in a random utility framework following other recent studies (Ghimire, Wen-Chi, Rudra and Shrestha, 2015; Kohansal and Firoozzare, 2013; Asfaw *et al.*, 2012).

$$U_i^* = X_i^{'}\gamma + u_i \qquad (3.1)$$

With $$U_i = \begin{cases} 1 \; if \; U_i^* > 0 \\ 0 \; Otherwise \end{cases}$$

Where;

U_i=latent variable representing the probability of a household to adopt improved rice technology or participate in the output market. The latent variable (U_i) takes the value of 1 if a rice producing household adopt improved rice technology or participates in the output market and, 0 otherwise.

Xi'= explanatory variables explaining the adoption and participation decisions of rice producing households.

γ = vector of parameters to be estimated.

u_i =error term.

A farmer switches from traditional to improved technology only if utility achieved from the latter is higher than from the former and a farmer will participate in the output market only if utility of participation is higher than not participating. This study employs the utility maximisation theory, to describe responsiveness of farmers to technology adoption and market participation (Kostov and Davidova, 2012; Martey *et al.*, 2012; Adesina, 1996; Adesina and Seidi, 1995).

Adoption of rice production technologies

Smallholder farmers' choice to adopt improved rice production technologies can be described using the theory of utility. A typical rice farmer or household will adopt improved rice production technology to make best use of his objective for engaging in rice production, while at the same time reducing associated risk (Strauss, Bednar and Mees 1989). The decision is built on how much benefit is derived from the change in practices and adopting new technologies. The principal question about this decision is often related to how much compensation would make the individual farmer not to respond to the new innovation.

In Ghana, farmers try or experiment different rice technologies. In this study we will consider the sustained decision to adopt any rice production technology continuously for more than two years to be based on risk (to gain or lose). We consider a risk averse rice household (H_i) that opts for a number of rice production technologies (T_j). With reference to Ali and Erenstein (2017), it is expected that rice producing households that have embraced any rice production technology have higher utility points equated to those that have not adopted:

$$U\,[H\,(T_1)] > U\,[H\,(T_0)] \tag{3.2}$$

It is further assumed that rice producing households adopting two technologies have higher utility points equated to households having adopted only one rice production technology.

$$U\,[H\,(T_{1,}\,T_2)] > U\,[H\,(T_{0,}\,T_1)] \tag{3.3}$$

From the above, it is assumed that the greater the utility points the more a rice production household will adopt new technologies and vice versa.

Market Participation

The theory of trade and utility forms the foundation of the study of market participation of smallholder rice producing households. This study is basically based on Barrett (2008) behavior of market participation model which is mainly focused on the maximization of utility. The main reason for the adoption of such methods is that market participation embroils two way decisions; the decision to participate and the actual degree of participation.

With reference to Siziba *et al.* (2011) who explained the theory of trade propounded by Ricardo. Rice producing households are fundamentally driven to participate in the output market (Trade) so that they can enjoy a different consumption package and improve their welfare from participating in the market by concentrating on providing products (Agricultural outputs) for which they have comparative advantage, and exchange for those they have no comparative advantage.

Farm household's utility is defined as a function of consuming a bundle of commodities and will therefore intend to maximize utility. Rice producing households earn income from sale of rice and other farm produce using different technologies. A rational household will only participate in the output market if the expected utility (U) to be gained from participating (P_1) is greater than not participating (P_0).

$$U(P_1) > U(P_0) \tag{3.4}$$

According to Barrett (2008), this process is influenced by privately held assets (land, labor, livestock, machinery), public goods and services (roads, extension services, training, radio broadcast, markets, etc.), household-specific characteristics (e.g. educational attainment, gender and age), non-farm income activities and decisions on output distribution that may affect search costs, negotiation skills, among others. Additionally, farm households also earn income from off-farm activities.

Rice producing household's choice to participate in the output market can be represented as a constrained optimization problem where a rice producing household intends to maximize utility subject to the expected income from sale of rice given available resources. A farm household may participate as a buyer or seller, Boughton *et al.* (2007) explained that a farm household can be a net buyer, net seller or be in the autarchic state. Barrett's model on household's participation in output market reflects a fundamental relationship between market participation of households as sellers and some variables which serve as explanatory variables.

A number of studies (e.g. Musah, 2013; Martey *et al.*, 2012; Siziba *et al.*, 2011; Omiti *et al.*, 2009) have included forms of these covariates (Private and public assets, location and transaction cost, income sources, product price, etc.) to access the determinants of market participation among farmers.

3.5.2 Conceptual Framework of Technology Adoption and Market Participation

A farmer in this study is considered as an adopter if the farmer has continuously used any of the rice production technology for more than two years preceding the year 2015 cropping season. The study assumes that before a farmer decide on adopting, the farmer would have been aware of the rice production technology, would have tried it for at least two years and then accept to use the technology. A farmer's arrival at the decision to use a particular rice technology passes through a number of internal (socioeconomic) and external (e.g., environmental or institutional) factors. The final decision to continue using the technology can be described or influenced by internal and external factors. The Conceptual Framework of Technology Adoption and Market Participation below is based on review of literature on technology adoption and market participation (see Figure 3.2).

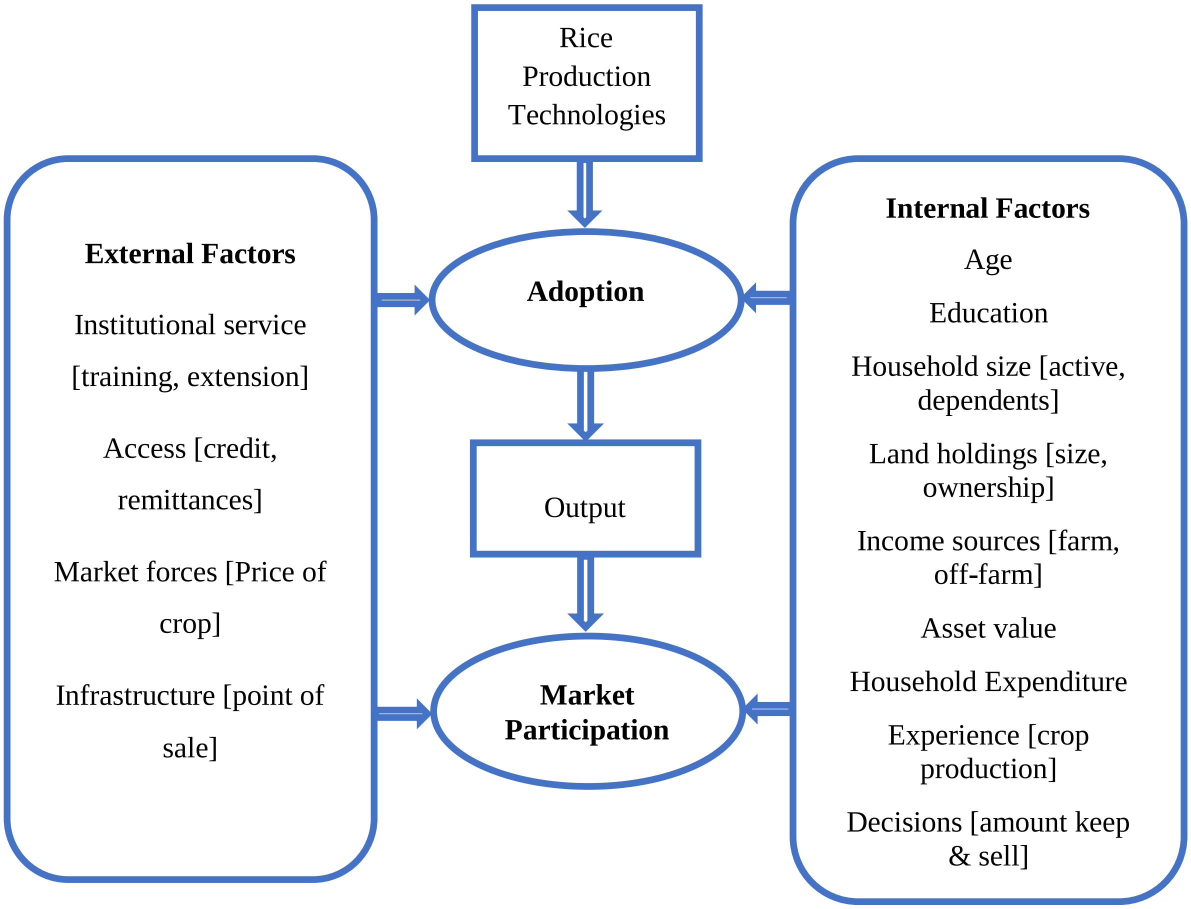


Figure 3. 2: Conceptual Framework of Technology Adoption and Market Participation
Source: Adopted from Abid *et al.* (2015)

3.5.3 Factors that affect the adoption of improved rice production technologies

Rice production technologies to be evaluated are bunding, dibbling/drilling, use of improved varieties, fertilizer and herbicides. Adoption of any of this technologies is defined as using any of the technologies continuously at least from 2013 to 2015 (more than two years). For a rice farmer to be considered as an adopter of any of the above production technologies, information on a farmer's first adoption, discontinuation and re-adoption consecutively for two years was obtained.

First Adoption: Farmers were asked if they had ever used any of the technologies for rice production. If yes, year they used technology the first time?

Discontinuation: Given that a farmer has ever used any of the rice technologies, farmers were asked if they discontinued the use of any technology at any point. If yes, the year the farmer discontinued the use of technology. If there are several times of discontinuation, farmer was asked to provide the last one (year).

Re-adoption: If a farmer discontinued the use of any of the technology after first adoption, they were ask if they re-adopted the technology. If yes, the year they re-adopted the technology. If there were several times of re-adoption, farmers were asked to provide last one (re-adoption year) after the last time they discontinued the use of the technology.

A rice farmer was therefore considered as an adopter of any technology;

1. If after first adoption the farmer did not discontinue use of the technology and the number of years is more than two.

2. If the farmer discontinued use of technology and readopted, then a farmer is considered as an adopter if the number of years is more than two from the last year of re-adoption.

Based on the above, a rice farmer is considered as a non-adopter of any of the technologies if the farmer does not meet the two criteria above.

Proposed model for assessing factors that affect the adoption of improved rice production technologies is Multivariate probit model. The multivariate probit model estimates several correlated dichotomous outcomes together because it simultaneously capture the impact of the set of covariates on each of the technology options, at the same time allowing for the possible relationships among unobserved disturbances, as well as the relationships between the decisions to adopt different technologies (Greene, 2012). The multivariate probit model can be seen as an extension of the univariate probit model, since it allows estimating several probit models simultaneously, while allowing the error terms in those models to be correlated (Greene, 2003). Ignoring the correlation across error terms would lead to inefficient coefficient estimates and thereby leading to inaccurate conclusions (Hsiao, 2003). Correlation occurs when unobservable characteristics (e.g., intrinsic ability or skill of individual rice farmers) captured in the error terms influence the adoption decision of rice producing farm households. Significantly positive correlations in the error terms have been interpreted as evidence of complementarity between technologies, whereas significantly negative correlations have been interpreted as evidence of substitutability (Asfaw *et al.*, 2016; Ndiritu *et al.*, 2014; Khanna, 2001; Dorfman, 1996). This relies on the assumption that unobserved heterogeneity is uncorrelated with explanatory variables.

Smallholder farm household's decision of whether or not to adopt any of the technologies is considered under the general frame work of utility or profit maximization (Tura and Hamo, 2018; Djalalou *et al.*, 2015). It is assumed that a given rice producing household is represented by i, and the set of rice production technologies represented by j^{th} making provision for non-exclusive alternatives that constitute the decision making to make a choice of a particular technology given other technologies. The choice sets may differ according to the individual households. Consider the i^{th} household (i = 1, 2…...N) facing a choice constraint on whether or not to adopt any of the rice production technologies. Let U_T represent the benefit a farm household will enjoy if they choose the j^{th} rice production technology: where T denotes the decision to adopt improved rice variety (Y_1), fertilizer

(Y_2), bunding (Y_3), herbicides (Y_4) and dibbling or drilling (Y_5). Rational farm households will adopt the j[th] rice technology if;

$$Y_{ij}^{*} = U_{j}^{*} - U_{0} > 0 \qquad (3.5)$$

The net benefit (Y_{ij}^{*}) that a farm household derives from adopting a rice technology is a latent variable determined by observed explanatory variable (X_i) and the error term (ε_i):

$$Y_{ij}^{*} = \beta_{j}^{'} X_{ij} + \varepsilon_{ij} \qquad (3.6)$$

j= (Y_1, Y_2, Y_3, Y_4, Y_5)

ε_{ij} = error terms distributed ($\varepsilon_{i1}, \varepsilon_{i2}, \varepsilon_{i3}, \varepsilon_{i4}, \varepsilon_{i5}$)

X_{ij} =vector of explanatory variables (X_{i1}, X_{i2}, ………. , X_{i17})

$\beta_{j}^{'}$ =parameter vectors (β_1 β_2 β_3 β_4 β_5)

Thus, the econometric approach for this study is by using the indicator function; the unobserved preferences (Y_{ij}^{*}) in equation (3.6) above and translate it into the observed binary outcome equation for each choice of rice technology as follows;

$$Y_{ij} = \begin{cases} 1 \; if \; Y_{ij}^{*} > 0 \\ 0 \; if \; Y_{ij}^{*} \leq 0 \end{cases} \qquad (3.7)$$

Given that **j**= (Y_1, Y_2, Y_3, Y_4, Y_5)

In multivariate probit model, where rice farm households have several choices of technologies to adopt, the error terms jointly follow a multivariate normal distribution (MVN) with mean zero and a normal to unity variance (for identification of the parameters) where (μ_{x1}, μ_{x2}, μ_{x3}, μ_{x4}, μ_{x5}) MVN~(0, Ω) and the symmetric covariance matrix Ω is given by:

$$\Omega = \begin{bmatrix} 1 & \rho x_1 x_2 & \rho x_1 x_3 & \rho x_1 x_4 & \rho x_1 x_5 \\ \rho x_2 x_1 & 1 & \rho x_2 x_3 & \rho x_2 x_1 & \rho x_2 x_5 \\ \rho x_3 x_1 & \rho x_3 x_2 & 1 & \rho x_3 x_1 & \rho x_3 x_5 \\ \rho x_4 x_1 & \rho x_4 x_2 & \rho x_4 x_3 & 1 & \rho x_4 x_5 \\ \rho x_5 x_1 & \rho x_5 x_2 & \rho x_5 x_3 & \rho x_5 x_4 & 1 \end{bmatrix} \qquad (3.8)$$

The off-diagonal elements represented by one (1) in the covariance matrix in the above equation (3.8) is of specific interest since it indicates the unobserved relationship (correlation) between the stochastic components of the various rice production technologies. This assumption means that equation (3.8) generates a multivariate probit model that jointly represents decision to adopt a particular rice technology. This specification with non-zero off-diagonal elements allows for correlation across error terms of several latent equations, which represents unobserved characteristics that affect the choice of several rice production technologies. Cappellarri and Jenkins (2003) specified the log-likelihood function associated with a sample outcome as follows:

$$\ln L = \sum_{i=1}^{N} \omega_i \ln \Phi(\mu_i, \Omega) \qquad (3.9)$$

Where ω is an optional weight for farm household i and Φi is the multivariate standard normal distribution with arguments μ_i and Ω, where μ_i can be denoted as:

$$\mu_i = (j_{i1}\beta_1 X_{i1}, j_{i2}\beta_2, j_{i3}\beta_3 x_{i3}), \qquad (3.10)$$

while Ω_{ik}= 1 for T=j and

$$\Omega_{jT} = \Omega_{Tj} = T_{ij} T_{iT} \rho_{jT} \qquad (3.11)$$

For T≠j, j=1, 2, 3….with $j_{ij} = 2y_{ij}-1$

Hypothesized variables

The potential variables, which were expected to influence household's adoption decisions are captured below.

Table 3. 1: Description, Measurements and Expected signs of explanatory variables (Multivariate probit model)

Variable	Description	Measurement		Expected Sign
Dependent Variables				
Imprv_Var	Improved varieties	Dummy: 1 = if yes; 0 = otherwise		
Chem_Fert	Chemical fertiliser	Dummy: 1 = if yes; 0 = otherwise		
Dib / drill	Dibbling / drilling	Dummy: 1 = if yes; 0 = otherwise		
Herbicides	Herbicides	Dummy: 1 = if yes; 0 = otherwise		
Bunding	Bunding	Dummy: 1 = if yes; 0 = otherwise		
Explanatory Variables				
Hh_Sal	Salaried head	Dummy=1 if household head is self-employed, 0 otherwise		+
Prp_Active	Proportion active	Proportion of active household members		+
Nb_Crops	Number of crops	Number of crops cultivated in the household		-
Nb_Rc_Plts	Number of rice plots	Number of rice plots (fields) cultivated by household		+/-
Plt_Size	Size of rice plot	Average size of rice plot(field) in the household		+/-
Asset_Val	Current asset value	Current asset value (in Ghana cedis) of household		+
Exp	Expenditure	Total annual consumption expenditure (in Ghana cedis)		+
Size_plots	Size of rice plots	Total size of all rice plots (fields) in acres		+/-
Dist_plots	Distance to plots	Average distance (in kilometers) to rice plots		-
Yrs_Cult_Plt	Years cultivate plot	Number of years rice is cultivated on plot (field)		+
Nb_Fam_Lab	Total family labor	Total family labor involved in rice production (number)		+
Soil	Major type of soil	1=Clay, 2=loamy 3= Other (*Sandy, laterite, etc.*)	Clay	+
			loamy	+/-
			Other	+
Lnd_Ownshp	land Ownership	1=Owned land, 2=Allocated 3=Family land, 4=other (*rented in, rented out, village chief, government, etc.*)	Owned land	+
			Allocated	+
			Family land	+
			other	+/-
Training	Source of training	1=Government (*MoFA, SARI*), 2= Non-Governmental Organization (NGO) 3=Other	Government	+
			NGO	+
			Other	+

3.5.4 Effect of improved varieties on the yield of rice

The theoretical framework of technology adoption under partial population exposure proposed by Diagne and Demont (2007) was used to assess the effect of adopting improved rice varieties on yield of rice. This is relevant because though a number of improved rice varieties have been released there is no certainty that all rice farmers are aware of their existence. The Effect of improved varieties on the yield (outcome variable) of rice was constructed within the counterfactual framework. Theoretically, the counterfactual framework allows assessors to determine the effect between treatment group (improved seed) and outcome (yield). The key challenge in this evaluation approach is that the counterfactual cannot be directly observed and must be approximated with reference to a comparison group. The treatment effect appraisal method was adopted to ascertain the effect of using improved variety on rice yield due to its ability to produce consistent estimates (Imbens and Wooldridge, 2009). Particularly the average treatment effect (ATE) methodological framework was adopted to evaluate the effect of improved variety on yield. The average treatment effect approach considers a "treatment" (exposure to improved variety) as necessary condition for knowing its effect on yield (outcome). Yield (Y) of rice producing households is the output of two types of varieties (Improved varieties and non-improved varieties), given that a household cultivates a particular type of variety (V) such that;

$Y = Y_0$ if $V = 0$ and

$Y = Y_1$ if $V = 1$

Where;

Y_1= Yield per acre from cultivating improved varieties

Y_0= Yield per acre from cultivating non-improved varieties

V_1= Improved variety

V_0=Non-improved variety

The ATE is the average effect (yield per acre) that would be observed if all farmers in the treated (adopters) and the control groups (non-adopters) received treatment (adopted improved varieties), compared with if no farmer in both groups adopted (Harder, Stuart and Anthony, 2010). In contrast to the ATE, the ATT refers to the average difference in yield that would be found for farmers who adopted improved varieties compared with if none of these farmers in the treated group had not adopted improved varieties.

Therefore, the average treatment effect for a randomly selected rice producing household is expressed as:

$$ATE = E(Y_1 - Y_0) \qquad (3.12)$$

The ATE is the average effect, at the population level (for both adopters and non-adopters). It is the average effect of moving sampled farmers from untreated (non-adopters of improved varieties) to treated (adopters of improved varieties). This estimates the expected yield per acre if farmers were to adopt improved rice varieties.

The ATT is the average effect, at the treatment level, this estimates the average difference in yield per acre within adopters of improved varieties. The ATT estimates the expected causal effect (yield per acre) of the treatment (improved varieties) for farmers who have adopted. The ATT and the ATE are referring by estimations to different portions of the population of interest (either within only adopters or both adopters and non-adopters).

Given the treatment status, the average treatment effect on the treated (ATT) which measures the effect of adoption on households who cultivated improved variety of rice (i.e. V=1) is given as:

$$ATT = E((Y_1 - Y_0)|V = 1) \quad (3.13)$$

However, these parameters are not observable, since they depend on counterfactual outcomes (What would have been the yield of adopters if they had not adopted improved variety of rice). Given the fact that the average of a difference is the difference of the averages, the ATT can be rewritten as:

$$ATT = E(Y_1|V = 1) - E(Y_0|V = 1) \quad (3.14)$$

The average yield per acre that adopters (households that adopted improved varieties) would have obtained if they did not adopt improved variety cannot be observed. In such types of casual inference, the estimation of treatment effects in the absence of information on the counter-factual (what would have happened) poses an empirical problem known as the problem of filling in missing data on the counter-factual (Becker and Ichino, 2002; Dehejia and Wahba, 2002; Rosenbaum and Rubin, 1983).

The challenge is that we only observe yield (Y_1) only for farm households who adopted improved rice varieties. The problem of missing data arises because it is not possible to measure the yield of individual farm households at each moment (Yield for adopters and yield for non-adoption) since each farm household has either adopted improved variety or not and hence a rice farmer cannot be both (adopter and non-adopter at the same time).

The challenge is to find a suitable comparison rice producing households with similar characteristics and whose yield provide a comparable estimate of yield if they were not to adopt improved variety.

Diagne and Demont (2007) explained that non-exposure bias or self-selection bias may arise from calculated rates of adoption and this may yield biased and inconsistent estimates of population adoption rates and their determinants. It is assumed that farmers who are not exposed to improved rice variety cannot adopt it and additionally, farmers who have adopted improved rice variety have some information about improved variety. Consequently, estimating adoption of improved rice variety is subject to non-exposure bias because there was no control for prior exposure or awareness. Therefore, estimating the adoption of improved rice variety will be composed of the combined probability of exposure and adoption. They further explained that due to continual process of diffusion, non-exposure bias may arise since not all farmers may be aware or informed of improved variety to make a choice and this may result in the underestimation of the true adoption of improved variety among rice farm households (farmers).

Awareness or exposure can be partly the choice of a farmer since a farmer may decide to participate or not participate in an agricultural activity hence become non-exposed. Since some farmers may be aware of improved rice varieties and others not aware, estimating the adoption of improved variety from sub-population that is aware may be prone to self-selection bias which may overestimate the real adoption rate of improved rice varieties.

Self-selection among rice producing households is one of the primary constrain with evaluation studies given that adoption of improved varieties may depend on unobserved characteristics of some rice producing households especially where there is no baseline information to assess the behaviour of households that adopted improved varieties prior to their decision to adopt (Abate, 2013). Adoption of improved rice varieties by households was not random and exogenously determined.

Due to the issues of non-exposure bias and selection bias, the causal effects of the determinants of adopting improved rice variety cannot be consistently estimated using a simple Probit, Logit, or Tobit adoption model that does not control for exposure (Besley and Case, 1993; Dimara and Skuras, 2003). This study adopted the Multivariate Distance Matching (MDM) technique and the Propensity Score Matching (PSM) technique to estimate the effect of the treatment (improved variety) on the outcome (yield).

Propensity Score Matching (PSM) technique

The Propensity Score Matching (PSM) procedure was used to control for the selection bias since it accounts for the differences in yield of the adopters of improved varieties and non-adopters (Francesconi and Heerink, 2010; Bernard, Taffesse and Gabre-Madhin, 2008). The PSM approach is an example of a non-parametric technique which does not require functional form and distributional assumptions (Asfaw, 2010). Using PSM to compute casual effect is considered as nonparametric although parametric regression model is used to estimate propensity score in the first stage via a probit or a logit model. Propensity matching or stratification is not bound by assumptions compared with regression models which have specific assumptions and specifications such as linearity, normal distribution of error term and interaction assumptions that must be met. As a result, the causal effects estimated with regression models can vary substantially depending on different specifications and assumptions of the model. Thus, using the PSM to calculate the causal effect is less susceptible to the violation of model assumptions.

The Propensity Score Matching (PSM) procedure fundamentally matches adopters and non-adopters of improved rice varieties according to their predicted propensity of adopting improved varieties (Smith and Todd, 2005; Wooldridge, 2005; Heckman, Ichimura, Smith and Todd, 1998; Rosenbaum and Rubin 1983). The conditional probability of adopting improved variety (propensity score) is estimated in the first stage via a Probit model by controlling for observed household characteristics. The Average treatment effect on the treated (ATT) is estimated in the second step using various matching approaches. After computing the propensity scores for sampled farmers, adopters and non-adopters are matched based on their propensity scores using different matching algorithms. Several matching methods have been proposed in the literature. The most widely used are Nearest-Neighbour Matching, Caliper Matching, Radius Matching and Kernel Matching. A summary approach of each matching algorithm estimator is discussed below.

Nearest Neighbour match treated (adopters) and control (non-adopters) of improved rice varieties matching individual farmers who adopted and searching for a non-adopter rice farmer with the closest in terms of propensity score (the Nearest Neighbour). This approach can be implemented with or without replacement during matching. The approach is applied with replacement when farmers who did not adopt improved variety can be used more than once (severally) as best match with adopters. In terms of matching without replacement non-adopters can be matched only once with adopters. Once each farmer from the adopted group is matched with a non-adopter, the difference between the yield of the adopters and the yield of the matched non-adopters is calculated. ATT is then obtained by averaging the differences in yield computed. Although all adopters find a match with non-adopters, it is evident that some of these matches are objectively poor because for some adopters the nearest neighbour may have a propensity score that is not close (different) to a matched non-adopter, nevertheless, this would contribute to the estimation of the effect of improved variety on yield independent of this difference. This is of particular interest with data where the estimated propensity score distribution among farmers is very different in the adopters (treatment) and the non-adopters (control).

Caliper and Radius Matching imposes a tolerance level on the maximum propensity score distance (caliper) between adopters and non-adopters treatment groups. This approach avoids the risk of bad matches faced by Nearest Neighbour Matching if the closest neighbour (in terms of propensity score) is far away from the comparison group. Imposing a caliper help avoid bad matches and hence the matching quality improves. Imposing a caliper in matching means that individual farmers who did not adopt (comparison group) are chosen as a matching partner for a farmer who adopted (treated group) that lies within the caliper (propensity score range) and are closest in terms of their propensity scores. A drawback of this approach is that it is difficult to know *a priori* what choice for the tolerance level is reasonable (Smith and Todd, 2005). Radius matching is a modified form of the caliper matching. The major difference is that the radius matching use not only the nearest neighbour within each caliper but all of the comparison farmers within the caliper (Dehejia and Wahba, 2002). The advantage of radius matching is that it uses only as many comparison farmers as are available within the propensity score range (caliper) and therefore allows for usage of extra (fewer) farmers when good matches are (not) available. Radius matching is characterized by oversampling but avoids the risk of bad matches.

Kernel Matching is a non-parametric matching estimator that uses weighted averages of all farmers who did not adopt improved variety (untreated group) to construct the effect of adoption on yield (counterfactual outcome). One major advantage of kernel matching approach is that it gives a lower variance which is achieved because more information is used. Kernel matching can be seen as a weighted regression of the counterfactual outcome on an intercept with weights given by the kernel weights (Smith and Todd, 2005). Weights depend on the distance between each farmer from the non-adopter group and the adopter group for which the estimated differences in yield is estimated. The weights that are used in kernel matching places higher weight on farmers close in terms of propensity score and lower weight on farmers with more variation in their propensity scores.

Propensity score matching algorithms differ not only in the way they measure the degree of similarity between adopters and non-adopters (the way they find matches between treatment groups) but also with respect to the weight they assign to the matched units. Nearest neighbour and Kernel matching algorithms were adopted to calculate the average effect of improved variety on yield.

Additionally, Rosenbaum bounds sensitivity post estimation analysis was performed to ascertain the sensitivity of the matching results to unobservable characteristics. This is important because the estimation of treatment effects with matching estimators is based on observable characteristics of rice farmers and a sensitivity analysis is performed to ascertain if any unobservable characteristic influence the effect of adoption on yield. If unobserved characteristics of farmers affects adoption (treatment) and yield (outcome) variables concurrently, a hidden bias might arise. A sensitivity analysis will make it clear that matching estimators are not robust against hidden bias if unobserved characteristics influenced both adoption and yield. Rosenbaum bounds sensitivity analysis will help to determine how strongly an unmeasured variable (farmer characteristics) must influence the selection process in order to undermine the implications of matching results. This is to ensure that results are not sensitive to omitted variables. Rosenbaum bounds sensitivity post estimation analysis helps us to ascertain if conclusion about the effect of adoption on yield (treatment effect) may be altered by unobserved characteristics (Rosenbaum, 2002).

Multivariate Distance Matching (MDM)

This new approach for Stata is a user written command by Jann (2017) and was partly in response to a paper by King and Nielsen (2016) titled “Why propensity scores should not be used for matching”. Multivariate Distance Matching is an alternative to using Propensity Score matching. Multivariate Distance Matching match adopters and non-adopters of improved variety based on a distance metric that measures the proximity between farmers (adopters and non-adopters) taking into consideration the difference (distance) in the measured (observed) characteristics between adopters and non-adopters compared with Propensity Score matching which uses the predicted propensities from the observed characteristics. The impression is to use observations that are “close” but not necessarily equal as matches. Common approach is the use of geometric distances to analyse similarities between a pair of subjects. The use of cluster analysis in summarising results in various research studies has also become popular. For instance, in principal components analysis it is promising to use the Weighted Euclidian distance (straight-line distance between two points) between the subjects and then the most similar pair can be clustered in a group. The Weighted Euclidian distance that is often used is the Euclidian distance from standardised variables. However, the Mahalanobis matching distance metric differs from the Weighted Euclidian distance because, instead of using the diagonal matrix with variances to standardise the variables, it uses the complete variance and covariance matrix, which means that the relation between the variables are included in the analysis (they are not treated as independent as in the Euclidian distance). This study adopted the Mahalanobis matching distance metric with regression adjustments to remove remaining imbalances after matching. The Multivariate Distance (MD) matching approach is specified below;

$$MD(Xi, Xj) = \sqrt{(Xi - Xj)' \sum^{-1} (Xi - Xj)} \quad (3.15)$$

Where;

Xi =Covariates for adopters of improved rice variety

Xj = Covariates for non-adopters of improved rice variety

Σ =is the covariance matrix of X which makes it possible to match based on multi-dimension (X) compared to PSM where the treatment probability is conditioned on X (propensity score), (Rosenbaum and Rubin 1983).

Propensity Score Matching (PSM) technique simplifies the matching task as we match on one-dimension based on propensity π(X) instead of multi-dimensional X (Jann, 2017). Various matching algorithms can then be used to find potential matches based on Multivariate Distance or estimated propensity π(X) and determine the matching weights. Theoretical results suggest that MDM will generally outperform PSM in terms of efficiency (King and Nielsen, 2016; Frolich, 2007). The “kmatch md” command was used to calculate the ATT value by giving larger weight to controls (non-adopters of improved varieties) with smaller distances.

Table 3. 2: Description and measurement of variables (MDM and PSM)

Variable	Description	Measurement	Equation Type
Dependent Variables			
Imprv_Var	Improved varieties	Dummy: 1 = if farm household cultivates improved variety; 0 = otherwise	TRT
Yield	Yield (Bags/Acre)	Number of bags (96 kg per bag) harvested per acre	OUT
Explanatory Variables			
Hh_Age	Age of head	Age of household head (years)	TRT
Hh_Mstats	Head married	Dummy=1 if household head is married, 0 otherwise	TRT
Hh_Sal	Salaried head	Dummy=1 if household head is self-employed, 0 otherwise	TRT/ OUT
Prp_Act_Edu	Active educated	Proportion of active household members educated	TRT/ OUT
Nb_Crops	Number of crops	Number of crops cultivated in the household	TRT/ OUT
Plt_Size	Size of rice plot	Average size of rice plot(field) in the household	TRT/ OUT/ REG
Yrs_Cult_Plt	Years cultivate plot	Number of years rice is cultivated on plot (field)	TRT/ OUT/ REG
Train	Training	Dummy=1 Household received training on rice production, 0 otherwise	REG
Nb_Train	Number Trained	Number of household members trained in rice production	TRT/ OUT
Nb_Lvstck	Number of livestock	Tropical Livestock Units (TLU)	TRT/ OUT
Nb_Fam_Lab	Total family labor	Total family labor involved in rice production (number)	TRT/ OUT/ REG
Dibb/ drill	Dibbling / drilling	Dummy: 1 = if yes; 0 = otherwise	TRT/ OUT/ REG
Qty1_Fert/Acr	Quantity fertilizer (1st)	Quantity of fertilizer used per acre for first application. Number of bags (50 kg bags) applied per acre	TRT / OUT/ REG
Qty2_Fert/Acr	Quantity fertilizer (2st)	Quantity of fertilizer used per acre for second application. Number of bags (50 kg bags) applied per acre	TRT/ OUT/ REG
Lnd_Ownshp	Land ownership	How land was acquired. 1=Owned land, 2=Allocated Family land, 4=other (*rented, village chief, government, etc.)*	TRT/ OUT
Soil	Soil Type	Major type of soil. 1=Clay, 2=loamy, 3=Other (*Sandy, laterite, etc.)*	OUT / REG
Seed_Src	Source of seed	Source of seed, 1=Institution or NGO, 2=Market 3=Own seed 4=Other	TRT/ OUT/ REG

Note: *Procedure for calculating Tropical Livestock Units (TLU) is explained below*

Equation Type*, **TRT**=Treatment equation for adoption of improved variety,

OUT=Outcome equation for Yield,

REG=Regression adjustments

Procedure for calculating Tropical Livestock Units (TLU)

The livestock unit is a reference unit for the aggregation of livestock from various species and age via the use of specific coefficients established on the basis of the nutritional requirement. The categories looked at are cattle, horses, donkeys, rabbits, sheep, goats, pigs and poultry (chicken, guinea fowls, ducks, turkeys, etc.). For global Livestock Units useful for comparing across countries, continents and systems, where 1 livestock unit is 1 cow in USA and a livestock unit for Sub-Saharan Africa using 1 livestock unit as 1 mature cow of 250 kg (TLU, 2011; FAO, 2003).

The Food and Agriculture Organization's Tropical Livestock Unit is based on the weight of the animal raised to the power of 0.75, compared with the equivalent figure for a "tropical cow" of 250 kg weight. With reference to the Food and Agriculture Organization's livestock units, the conversion equivalents of Sub-Saharan Africa livestock into Tropical Livestock Units (TLU) is 0.50 for cattle, 0.80 for horses and donkeys, 0.03 for ducks, turkeys and geese, 0.02 for rabbits, 0.10 for sheep and goats, 0.20 for pigs and 0.01 for chicken and guinea fowls (Chilonda and Otte, 2006; FAO, 2003). Total livestock holding by household is computed by multiplying for each livestock type, the heads number (total) with the corresponding livestock unit coefficient. The total livestock holding by household is obtained by adding the livestock unit from each of the livestock after multiplying the total number of livestock with the corresponding livestock unit coefficient.

$$\text{Total livestock holding} = \sum_{i=1}^{n} TLU_i \qquad (3.16)$$

Where; n = number of livestock (type), TLU_i = Tropical Livestock Unit for type i.

3.5.5 Factors that influence the levels of market participation

The focus of this aspect of the research work is on the range of farmers transiting from subsistence to commercial production depending on the primary objective of the farmer. The rational is that farmers who are commercially oriented will sell all or greater proportion of their output while subsistence oriented farmers will sell very small proportion or not sell at all. There are also farmers who are within the transition zone (close to median) and are not so much commercially or subsistence oriented.

The proportions of output that farmers sell may or may not be their orientation. There are instances where the primary objective of smallholder farm households is to meet household food consumption but sell a greater proportion of their output and behave as if they are commercially oriented in cases where farm households are cash constraint especially in meeting health and educational expenses. On the other hand, their proportion (level) of participation in the market are associated with some characteristics and behaviours. Characteristics and behaviour of farmers whose level of participation are low in the output market may differ from farmers who participate moderately or high.

Quantile regression models different effects of variables on a response and allows for the size of the error term to vary across values of the independent variables (Koenker, 2005). The quantile regression model will vary across different quantiles (levels of participation in the output market). The quantile regression model is written as;

$$Y_i = X_i^T \beta_\tau + \mu_{\tau i} \tag{3.17}$$

Where;

i = individual agent (household/farmer)

τ = Quantile range (0< τ <1)

Y_i = Response variable

X_i = Vector of explanatory variable for household/farmer *i*,

β_τ = Quantile specific linear effects (Effect of a parameter at different quantiles)

$\mu_{\tau i}$ =Error term (Assumes a cumulative distribution function with a linear quantile restriction)

Kostov and Davidova (2012) clarified that quantile regression uses all available observations in estimating any quantile specific effect. A description of the quantile function given the linear quantile restriction (0< τ <1) is written as;

$$Q_{yi}(\tau \mid X_i) \tag{3.18}$$

Where;

X_i =response variable conditional on a vector of explanatory variables X_i at a given quantile.

The above can be written as;

$$Q_{yi}(\tau \mid X_i) = H_{yi}^{-1}(\tau \mid X_i) = X_i^T \beta_\tau \tag{3.19}$$

Based on the above, the advantage of the quantile regression model over linear regression is that in linear regression model the mean of the dependent variable is used across explanatory variables for description. Relations between independent and dependent variables are usually assumed to be the same at all levels with ordinary least squares (OLS) regression and related procedures but Quantile regression offers an alternative approach. In ordinary least squares regression, the aim is to minimize the distances between the values predicted by the regression line and the observed values. Quantile regression relaxes the common regression slope assumption and in contrast weights the distances between the predicted values by the regression line and the observed values separately, then tries to minimize the weighted distances. The slope of the regression line is allowed to vary across quantiles of the household commercialisation index in quantile regression procedure. Using ordinary least squares regression procedure estimates results based on the conditional mean (average) of the household commercialisation index (proportion of output sold) given certain values of the predictor variables. However, quantile regression procedure is aimed at estimating either the conditional median or other quantiles of the household commercialisation index. Estimations conditioned on the median or quantiles are not skewed so much by outliers (by extremely large or small values) and do not affect the median as strongly as they do to the mean and therefore quantile regression estimates are more robust against outliers in the response measurements. Adopting quantile regression will provide a greater flexibility than other regression methods to identify differing relationships at different levels of output participation based on the household commercialisation index (proportion of output sold). Additionally, models that use the mean of dependent variables is conditionally Gaussian, which means that the mean equation applies to all parts of the distribution but quantile regression makes no such distributional assumptions and hence, the conditional quantile function that is estimated can vary across quantiles (Kostov and Davidova, 2012; Koenker and Bassett, 1978).

Alternatively, Koenker and Bassett (1978) stated the conditional quantile by expressing it in the form of an optimization problem. The most popular linear quantile regression estimator is arrived by solving the optimization problem of the linear programming estimator of Koenker and Bassett, stated below.

$$\arg\min_{\beta_\tau} \sum_{i=1}^{n} \rho_\tau (y_i - X_i^T \beta_\tau) \qquad (3.20)$$

According to Koenker and Machado (1999), the minimisation problem in the above equation (3) can be recast as an equivalent maximum likelihood problem where the distribution of the response variable is skewed asymmetrically. Yu and Moyeed (2001) expounded the above equation and proposed a Bayesian version of quantile regression but this is conventional to the ordinary frequency approach appraisal which is not very robust. The dependent variable (level of participation) was computed using the household commercialisation index (HCI) proposed by Govereh, Jayne and Nyoro (1999) to estimate the levels of rice commercialisation. Household commercialization index (HCI) is used to measure the extent of commercialisation at household level. The HCI is an estimated index of the gross value of all rice sales per household per year to the gross value of all rice production. The index measures the orientation of farmers towards market participation which range from zero (0) to one (1). The interpretation of the HCI is that the closer the HCI is to one, the greater the level of output market participation. An advantage of the HCI is that it provides the level of commercialisation for every small holder farm household separately. HCI has been extensively adopted in studies to classify the levels of output market participation (Opondo, Dannenberg and Willkomm, 2017; Muricho, 2015; Musah, 2013; Martey *et al.*, 2012). This study maintained the actual proportions of the index without multiplying by 100 following the works of Ansah and Tetteh (2016).

$$HCI_{Rice} = \left[\frac{Rice\_Quantity(kg)\_Sold_{ij}}{Total\_Rice\_Output(kg)_{ij}} \right] \quad (3.21)$$

Where;

i= rice households (1,….429)

j= year (2015 farming season)

The level of market participation will be in proportions taking values from 0 (no sales) to 1 (all rice produce is sold). Fractional response models are extensively adopted in modelling a fractional response variable via transforming the original variable so that the interval constraint is not applicable, this is often done through a logit transform.

However, Kostov and Davidova (2012) explained that applying the logit transform given as $y^*= log(y/1-y)$, where *y* is the original commercialisation index (interval) and y^* *is the* transformed variable (fractional) or by using the opposite transform where $y=exp(y^*)/[1+exp(y^*)]$, such that after transformation *y* is certain to be in the (0,1) interval is problematic. They explained that the logit transform will be undefined when the fractional variable is measured at the boundary of the unit interval (when HCI is 0 for not selling any quantity or 1 for selling all rice output). The problem arises when the fractional variable is measured at the boundary of the unit interval (i.e. when it takes the value 0 or 1), because then the logit transform is undefined. The problem of logging zeros (0) and ones (1) arises and the transformation cannot hold. To overcome the above, it is proposed that the proportional variable be scaled so that values of zeros (0) and ones (1), now fall within (0, 1) interval. Following the works of (Bottai, Cai and McKeown, 2009; Kostov and Davidova, 2012) the scaling of the proportional variable can be achieved by replacing Y (proportional variable) by (*y*+*e1*)/ (1+*e2*). Y will therefore be computed as stated below.

$$Y = \left[\frac{y + e_1}{1 + e_2} \right] \tag{3.22}$$

Where;

e_1 and e_2 are random small values, such that $e_1 < e_2$.

Therefore (y+*e1*) moves *y* away from zero and dividing by (1+*e2*) scales back its values and as long as $e1 < e2$ the scaled values will be lower than 1. In this study the values of e1 and e2 were replicated from the work of Kostov and Davidova (2012) where;

$e_1 = 10^{-32}$ and $e_2 = 10^{-8}$

The above transformation approach maintains the ranking of the level of participation (proportion of output sold) compared with the latter, which is an essential property when using quantile regression. Additionally, this approach allows us to interpret the coefficients in the usual way with regard to their signs where greater coefficients point to a more influence.

The focus in this study is determining which factors influence the participation of rice farm households at different levels (corresponding quantiles). This will help ascertain factors that only influence farm households who participate low in the output market (lower quantiles) and farm household's who's participation is high. This study presented quantile regression results at quartiles (i.e. 0.25th, 0.5th and 0.75th) though some authors (Eide and

Showalter, 1998; Buchinsky, 1994) proposed that additional quantiles (0.05^{th} & 0.95^{th}) can be included to complement and summarise the results at the tails.

Additionally, farmers were categorised into three groups based on market participation for descriptive analysis. The study replicated the categorisation of farmers by Ansah and Tetteh (2016) and categorised farmers into the following:

1. Households with HCI below 0.25 (i.e., HCI $<$ 0.25) are grouped as subsistence farm households. The primary objective of these farm households is to meet their subsistence requirement compared with profit motive.
2. Households with HCI greater than or equal to 0.25 and less than or equal to 0.5 ($0.25 \leq$ HCI≤ 0.5) are categorised as transition farm households. This group of rice producing households are interested in meeting both household food requirement and earning income from output.
3. Households with HCI greater than 0.5 (HCI $\geq$ 0.5) are grouped as commercially (profit) oriented farm households. The primary objective of these group of farm households is to earn income from rice production.

Table 3. 3: Description, Measurement and Expected signs of variables (Quantile regression model)

Variable	Description	Measurement		Expected Sign
Dependent Variables				
HCI	Proportion Sold	Household Commercialization Index(HCI), Proportion of harvest sold (ratio)		
Explanatory Variables				
Hh_SelfEmp	Self-employed	Dummy=1 if household head is self-employed, 0 otherwise		+
Hh_Sal	Salaried head	Dummy=1 if household head is self-employed, 0 otherwise		-
Prp_Sch	Proportion school	Proportion of household members in school		-
Nb_Crops	Number of crops	Number of crops cultivated in the household		-
Nb_Rc_Plts	Plot Number	Number of rice plots (fields) cultivated by household		+
Imp_Var	Improved Variety	Cultivates improved varieties		+
Plt_Size	Size of rice plot	Average size of rice plot(field) in the household		+
Sel_Px_kg	Selling Price	Price per kilogram (GH/kg) at which rice paddy was sold		+
Train	Training	Dummy=1 Household received training, 0 otherwise		+
Hh_Radio	Own Radio	Dummy=1 Household member own working radio, 0= otherwise		+
Yield	Yield	Number of bags harvested per acre. Bags (96 kg per bag)		+
Place_Sell	Place of sale	Where largest quantity of rice paddy was sold. 1=Big town market, 3=Village market, 4=Farm gate, 5=Other (*Local trader or aggregator, etc.*)	Farm gate	+/-
			Village	+/-
			Big town	+
			Other	+/-
Dec_Amt_Kp	Decision Keep	Who mainly decides on amount of rice paddy to keep? 1=Husband & wife, 2=Wife's only, 3=Other (*Children, Husband only, all*)	Husband & wife	+
			Wife's only	+
			Other	+/-
Dec_Sell	Decision Sell	Who mainly makes decision to sell rice paddy. 1=Husband & wife, 2=Husbands only, 3=Other (*Children, Wife only, all*)	Husband & wife	+
			Husbands only	+
			Other	+/-

3.5.6 Intensity of participation in output market

This objective is to estimate factors affecting farmer's intensity of participation in the output market. A farm household is said to participate in the output market if the household sells a part of their output (rice paddy) in the market. Intensity of his participation is how much (quantity of output) the farmer has participated with. A rice producing household's intensity is measured as how much production (total harvest) the farm household off-loaded into the output market. The intensity of market participation is modelled as following.

$$I_i = X_i\lambda + \gamma P_i + \varepsilon_i \tag{3.23}$$

Where;

I_i= Quantity of rice paddy sold (in bags/kg)

ε_1= random normal distribution term

P_i= dummy variable (1 = Household participated in the market; 0 = Otherwise) showing commercialisation of output. If its value is 1 then it means farmer sell a part of his output in the market and zero means otherwise.

X_i= vector of explanatory variables.

The decision to participate in the market solely depends on farm households and if households decide to participate in the output market; that is farm households self-selects to participate or not. The choice to participate is not random but a decision or choice made by rice producing farm households. Hence, this study assumed that farm households are risk-neutral and will only participate to gain. The market participation of farm households can be estimated with the help of an index function expressed as follows;

$$P_i^* = X_{i\alpha} + V_i \tag{3.24}$$

Where;

P_i^*: Represents a latent variable showing the difference between utility obtained from participating U_{IP} in the output market and utility from not participating U_{IN} in the output market. The decision of farm households to participate in the output market requires that the following condition is met in the market.

$$P_i^* = U_{IP} - U_{IN} \tag{3.25}$$

Where;

$X_{i\alpha}$ = the explanatory variables which affect market participation
V_i= error term

It is predicted that market participation and how much (intensity of participation) households participate within the output market may be interdependent which we estimate through equation (3.23) and (3.24). Additionally, the problem of selection bias may occur if unobserved factors affect the error term of both intensity of participation equation (ε_i) and market participation (V_i). If this occurs there will be a correlation between the error term of equation (3.23) and (3.24). This means that the intensity of participation due to market participation will be biased due to unobserved factors.

Therefore, the estimation of equation 3.23 with ordinary least square (OLS) will result in biased estimates. To overcome this problem Heckman's two-step approach was applied in this study. Moreover, this is an appropriate model which corrects the problem of simultaneity. It is established in literature that the Heckman two-step approach can only be used when the correlation between the two error terms is greater than zero. If this holds, the two step procedure will correct the problem of selection bias (Johannes, Le, Zhou, Johnston and Dworkin, 2010; Siziba *et al.*, 2011).

According to Wooldridge (2010), this approach is based on the restrictive assumption of normally distributed error terms. In the first stage of the two-step approach, a probit model is used to identify the factors that affect market participation (equation 3.24) while OLS is applied in the second stage to examine the intensity of participation (equation 3.23). The probit model also provides the value of inverse mills ratio (IMR). The inverse mills ratio (IMR) is denoted by ' λ ' and is defined as ''the ratio of the ordinate of a standard normal distribution to the tail area of the distribution" (Greene, 2003). The inverse mills ratio (IMR) is specified as;

$$\lambda_i = \frac{\varphi(\rho + \alpha X_i)}{\phi(\rho + \alpha X_i)} \qquad (3.26)$$

Where;

φ = standard normal density function

ϕ = standard normal distribution function

According to Greene (2003), the inverse mills ratio (IMR) term corrects the problem of selection bias. If the term (λ_i) is not statistically significant, then sample selection bias is not a problem (Heckman, 1979). A statistically significant value of λ_i means that significant difference exists between farm households that participated in the market and those that did not participate. In estimating the intensity of participation, the above difference needs to be taken into consideration. The two-step Heckman's approach proceed as follows, the selection equation (first step) shows whether farm households participate in the rice output market or not and is specified as equation 3.27 below.

$$P = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 + \alpha_4 x_4 + \alpha_5 x_5 + \alpha_6 x_6 + \alpha_7 x_7 + \alpha_8 x_8 + \alpha_9 x_9 + \alpha_{10} x_{10} + \alpha_{11} x_{11} + \alpha_{12} x_{12} + \alpha_{13} x_{13} + \alpha_{14} x_{14} + \alpha_{15} x_{15} + \alpha_{16} x_{16} + \alpha_{17} x_{17} + \alpha_{18} x_{18} + \alpha_{19} x_{19} + \alpha_{20} x_{20} + v_i \quad (3.27)$$

The outcome equation (second step) which examines the effect of market participation on the intensity of participation, the equation is estimated employing OLS as follows.

$$I = \gamma_0 + \gamma_1 x_1 + \gamma_2 x_2 + \gamma_3 x_3 + \gamma_4 x_4 + \gamma_5 x_5 + \gamma_6 x_6 + \gamma_7 x_7 + \gamma_8 x_8 + \gamma_9 x_9 + \gamma_{10} x_{10} + \gamma_{11} x_{11} + \gamma_{12} x_{12} + \gamma_{13} x_{13} + \gamma_{14} x_{14} + \gamma_{15} x_{15} + \gamma_{16} x_{16} + \gamma_{17} x_{17} + \gamma_{18} x_{18} + \gamma_{19} x_{19} + \gamma_{20} x_{20} + \gamma_{21} IMR \quad (3.28)$$

Where;

P= Participation in output market (1=Participated, 0=otherwise)

I= Intensity of participation (Quantity of output sold)

α = Covariate coefficients of participation in output market

γ = Covariate coefficients of intensity of participation

IMR= Inverse Mills Ratio

$x_1, \ldots\ldots x_{20}$ = Covariates

Description and Measurements of Variables

Table 3.4 below give description of all variables used in running analysis to meet the objectives of the study. It gives narration on the variables and how each variable was measured.

Table 3. 4: Description, Measurements and Expected signs of variables (Heckman model)

Variable	Description	Measurement	Expected Sign
Dependent Variables			
Participation	Sell rice output	Dummy: 1 = if yes; 0 = otherwise	
Intensity	Quantity Sold	Number of bags (96 kilogram /bag) sold	
Explanatory Variables			
Hh_Age	Age of head	Age of household head (years)	-
Hh_Edu	Basic education	Dummy=1 Household head has attained basic education, 0 otherwise	+
Hh_SelfEmp	Self-employed	Dummy=1 if household head is self-employed, 0 otherwise	+
Hh_Size	Members	Number of household members	-
Prp_Active	Proportion active	Proportion of active household members	+
Prp_Sch	Proportion school	Proportion of household members in school	-
Nb_Crops	Number of crops	Number of crops cultivated in the household	-
Nb_Rc_Plts	Plot Number	Number of rice plots (fields) cultivated by household	+
Plt_Size	Size of rice plot	Average size of rice plot(field) in the household	+
Sel_Px_kg	Selling Price	Price per kilogram (GH/kg) at which rice paddy was sold	+
Train	Training	Dummy=1 Household received training, 0 otherwise	+
Prp_Cons	consumed	Proportion of harvest consumed by household	-
Recv_Remit	Remittances	Dummy=1 if household receive remittances, 0 otherwise	+/-
Asset_Val	Asset value	Current asset value (in Ghana cedis) of household	+
Nb_Lvstck	Livestock	Tropical livestock units	+
Exp	Expenditure	Total annual consumption expenditure (in Ghana cedis)	+
Hh_Phone	Own Phone	Dummy=1 Household member own working phone, 0=otherwise	+
Hh_Radio	Own Radio	Dummy=1 Household member own working radio, 0= otherwise	+
Yield	Yield	Number of bags harvested per acre. Bags (96 kg per bag)	+
DecAmt_Kp	Decision Keep	Who mainly decides on amount of rice paddy to keep? 1=Husband & wife, 2=Wife's only, 3=Other (*Children, Husband only, all*): Husband & wife	+
		Wife's only	+
		Other	+/-
Dec_Sell	Decision Sell	Who mainly makes decision to sell rice paddy. 1=Husband & wife, 2=Husbands only, 3=Other (*Children, Wife only, all*): Husband & wife	+
		Husbands only	+
		Other	+/-

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Chapter outline

Results and findings of the study are presented in this section. It presents a description of the socio-economic and demographic characteristics of rice producing farm households (section 4.2), adoption of rice production technologies (section 4.3), rice varieties cultivated (section 4.4), rice yield across adopters and non-adopters of improved rice varieties (section 4.5), market participation (section 4.6), factors determining the adoption of improved rice production technologies (section 4.7), effect of using improved varieties on yield (section 4.8) and determinants of the level and intensity of smallholder farmer's participation in output markets (section 4.9 and section 4.10) are presented.

4.2 Descriptive statistics of farm households

Demographic variables shape many facets of human lives and have been found to be indicators of farmer's attitude towards agricultural activities. This section discusses selected demographic characteristics of surveyed rice farm households.

Age Distribution of Household Heads

Age of rice farm household heads ranges from a minimum of 21 years to a maximum of 100 years with the average household age being about 46 years. Majority (40.3 percent) of farm households' heads are within the age bracket of 21- 40 years while 12 percent is above 60 years. This implies that majority of farm household heads in northern Ghana are within the economically active population. Younger farmers are typically less risk-averse and are more willing to try new technologies, additionally younger household heads are more dynamic with regards to adoption of innovations (Polson and Spencer, 1992). Refer to Table 4.1 below and appendix A

Gender of Household Heads

The distribution of farm household heads in terms of gender in this study was significant due to the immense role that gender stratification plays when it comes to the control and allocation of agricultural resources that both males and females require to engage in production. Of the 429 farm households, 26 were headed by females representing 6.1 percent of the total households with a significantly higher number of male headed households representing 93.9 percent. Most of the household decisions regarding agricultural production and resource allocation are more likely to be taken by men who are the majority that head households in the study area. Refer to Table 4.1.

Marital Status of Household Heads

On marital status of household heads, married heads were the predominant group representing 86.3 percent of households while about 13.7 percent are unmarried. Married farm household heads are more likely to get labour support from their spouses hence easily access family labour and also more likely to adopt labour intensive technologies. Married farm household heads do have opportunity of producing more output with the support of their spouses and hence are capable of raising more marketable surplus. In northern Ghana, marital status in addition to age is valued highly compared with younger and unmarried persons. Additionally, married male household heads have greater rights over their wife's and son's labour allocation than married women (Van de Walle, 2013; Udvardy and Cattell, 1992). Refer to Table 4.1.

Educational Status of Household Heads

Majority (66.67 percent) of farm household heads have not attained any education either from formal or non-formal institutions and 33.33 percent have attained some form of education. Out of the 33.33 percent of household heads that have gained some form of education, the majority (18.65 percent) went through non-formal institutions (Arabic and night school) and 14.68 percent through formal institutions. For household heads who attended formal educational institutions, 6.53 percent completed basic education, secondary (6.99 percent) and tertiary (1.40 percent). Formal education is a means of getting employed in the non-farm sector and given that only 6.1 percent of heads are salaried workers, majority of farm household heads are not able to involve themselves in formal non-farm economic activities. Farmers who are educated are most likely to be exposed or informed of agricultural technologies and may be willing to accept new innovations (Ali and Erenstein, 2017). Refer to Table 4.1.

Household Size

The average number of people living in a farm household was about 9 persons per household ranging from a minimum of 2 to a maximum of 65 persons. For active members, an average of 5 active members are found within each household. The proportion of active members in the household is about 56.14 percent. Majority (52.45 percent) of households have size between 6 to 10 members per household although about only 3.73 percent of farm households have over 15 members in a household. Farm household with large number of members have the ability to supply surplus labour to non-farm activities and income earned could be reinvested into farm activities in the form of adopting technologies (Ali and Erenstein, 2017; Gautam and Andersen, 2016). On the other hand, large household size can negatively influence market participation since the household will have more mouths to feed which will decrease the quantity of marketable surplus a household can advance to the output market. Additionally, a high proportion (56.14 percent) of household members are economically active. About 38 percent of household members are still in school and majority of those in school are children (dependents). Refer to Table 4.1.

Assets and Expenditure

In table 4.1, the mean total annual consumption expenditure of farm households is 15, 914.3 (Ghana cedis) ranging from a minimum expenditure of 312 (Ghana cedis) to a maximum of 335, 660 (Ghana cedis). Differences in household compositions and practises across locations may account for some households spending so much more than others. A regular farm household within the sample has an asset value of 11,019.4 (Ghana cedis) owning an average of about 40 livestock's (Goats, sheep, cattle, donkeys, pigs, chicken, ducks, guinea fowls, etc.)

Size of rice plot

In table 4.1, the average size of rice plot per farmer within a household is 2.67 acres and the average acreage used for rice production per household is 8.69 acres. The average number of rice plots (fields) cultivated by households is 2 plots ranging from a minimum of 1 plot to a maximum of 5 plots per household.

Table 4. 1: Descriptive statistics of explanatory variables (Continuous variables)

Variable	Description	Mean	Std. Dev
Age of head	Age of household head (years)	45.6760	13.1599
Basic education head	Dummy=1 Household head has attained basic education, 0 otherwise	0.0653	0.2473
Self-employed head	Dummy=1 if household head is self-employed, 0 otherwise	0.2867	0.4528
Sex of head	Dummy=1 Household head is male, 0 female	0.9394	0.2389
Married head	Dummy=1 Household head is married, 0 otherwise	0.8625	0.3448
Salaried head	Dummy=1 if household head is self-employed, 0 otherwise	0.0606	0.2389
Household members	Number of household members	8.3916	4.7302
Proportion active	Proportion of active household members	0.5614	0.1954
Proportion in school	Proportion of household members in school	0.3877	0.2497
Number of crops	Number of crops cultivated in the household	3.3986	1.3798
Number of rice plots	Number of rice plots (fields) cultivated by household	2.1119	0.8068
Size of rice plot	Average size of rice plot(field) in the household	2.6722	2.4199
Selling Price (GH/kg	Price per kilogram (GH/kg) at which rice paddy was sold	1.1908	0.3361
Training(Gov't)	Dummy=1 Household received training, 0 otherwise	0.2075	0.4060
Proportion consumed	Proportion of harvest consumed by household	0.3520	0.3178
Receive remittances	Dummy=1 if household receive remittances, 0 otherwise	0.0559	0.2301
Current asset value	Current asset value (in Ghana cedis) of household	11019.4	14731.0
Number of livestock	Number of livestock owned by household	39.457	215.006
Tropical livestock	Tropical livestock units	1.2727	5.1789
Expenditure	Total annual consumption expenditure (in Ghana cedis)	15914.3	34486.0
Household own phone	Dummy=1 Any household member own phone, 0 otherwise	0.7995	0.4008
Household own radio	Dummy=1 Any household member own radio, 0 otherwise	0.7995	0.4008
Years cultivate plot	Number of years rice is cultivated on plot (field)	14.8955	12.0094
Total family labour	Total family labour involved in rice production (number)	48.1243	69.3062
Size of rice plots	Total size of all rice plots (fields) in acres	8.6962	9.6714
Distance to rice plots	Average distance (in kilometers) to rice plots	3.1857	6.9353

Source: Survey Data 2015

Land holdings and Farm characteristics

The majority (73.89 percent) of households cultivate 2 to 3 plots of rice, 22 percent of households cultivate 1 plot and 3.96 percent cultivate 4 - 5 plots of rice in a household. The average number of years that rice is cultivated on plots is 15 years. Large farm size is likely to positively influence adoption of agricultural technologies (Abid, Scheffran, Schneider, Ashfaq, 2015) and resulted output likely to improve participation in market. Other authors (Javed *et al.*, 2015) found mixed results. Refer to table 4.2.

Access to farm land is an essential agricultural productive asset and sometimes ownership of land is an indicator of wealth. In table 4.2, land for rice production is mainly on farmers own land (67.60 percent) or allocated family land (25.41 percent). A small proportion (6.99 percent) of farmers also access rice plots through allocation by village chiefs, use of government lands, renting, among other means.

In table 4.2 , a greater proportion (50.35 percent) of farm households categorised the soil on their rice plots as loamy soil, 39.63 percent as clayey soil and 10.2 percent as other type of soils (Sandy, laterite, etc.). Highly fertile rice plots are more productive with good return on investment compared with less fertile fields. Therefore, it is expected that farm households will place much resources and practise innovations on fertile soils, however this may not hold for soil fertility enhancing technologies since farmers will rather like to improve the fertility of poorer soils.

Access to Training and Extension

Farm households that have attended training or received extension service on rice production represented 29 percent of the total sample. About 20.75 percent of farm household's attended trainings while 16 percent received extension service. Government institutions (69.53 percent) led in the provision of training and extension service, followed by Non-governmental organisations (27.34 percent) and 3.13 percent from other sources. Refer to table 4.2.

Marketing factors

In table 4.2, most (53.85 percent) farm households indicated that husbands within households solely makes decision to sell the harvested paddy rice with only 13.99 percent indicating that the decision to sell paddy rice is made jointly by husbands and wife's within farm households. The survey also took information on where the largest quantity of rice paddy was sold. Majority (79.02 percent) of farm households sold their rice paddy at their home locations to local traders (mostly market women) and aggregators. Remaining farm households sold their paddy rice at big town markets (13.99 percent), village markets (4.66 percent) and farm gate (2.33 percent). Sale at farm gate refers to sale of paddy immediately after harvest without storage either at farmer's home location or farm.

The average price at which rice paddy was sold by farm households was 1.19 (Ghana cedis) per kilogram. Farm households however often sold rice paddy multiple times with varying prices depending on time of sale and place of sale. The lowest and highest price per kilogram recorded for sale of rice paddy was 0.63 and 2.5 (Ghana cedis) respectively. Refer to table 4.2. A greater proportion (79.95 percent) of farm households own at least a radio set and mobile phone.

Table 4. 2: Descriptive statistics of explanatory variables (Categorical variables)

Variable	Description		Freq.	Percent
Land ownership	How land was acquired. Owned land, Allocated family land, other (*rented in, rented out, village chief, government, etc.)*	Own plot	290	67.60
		Family	109	25.41
		Others	30	6.99
Training	Source of training. Government (*MoFA, SARI*), Non-Governmental Organisation (NGO), Other.	Government	89	69.53
		NGO	35	27.34
		Others	4	3.13
Soil type	Major type of soil. Clay, loamy, Other (*Sandy, laterite, etc.)*	Clayey soil	170	39.63
		Loamy soil	216	50.35
		Other	43	10.02
Decision amount to keep	Who mainly decides on amount of rice paddy to keep? Husband & wife, Wife's only, Other (*Children, Husband only, all*)	Husband & wife	45	10.49
		Wife's only	61	14.22
		Others	323	75.29
Decision to sell	Who mainly makes decision to sell rice paddy. Husband & wife, Husbands only, Other (*Children, Wife only, all*)	Husband & wife	60	13.99
		Husbands only	231	53.85
		Other	138	32.16
Place of sale	Where largest quantity of rice paddy was sold. Big town market, Village market, Farm gate. Other (*Local trader or aggregator, etc.*)	Big town market	60	13.99
		Village market	20	4.66
		Farm gate	10	2.33
		Other	339	79.02

Source: Survey Data 2015

Farm output

In table 4.3, the mean output of rice is 7.29 bags (96kg) per acre ranging from a minimum of 0.46 to a maximum of 28.78 bags per acre of rice plot. The wide gap observed in the output per acre may be due to the varied practises among rice producing households.

Table 4. 3: Descriptive Statistics of Dependent Variables

Variable	Description	Min	Max	Mean	Std. Dev
Improved varieties	Dummy=1 if household adopted improved variety, 0 otherwise			0.4685	0.4996
Chemical fertiliser	Dummy=1 if household adopted chemical fertiliser, 0 otherwise			0.4336	0.4961
Dibbling / drilling	Dummy=1 if household adopted dibbling/ drilling, 0 otherwise			0.3730	0.4842
Herbicides	Dummy=1 if household adopted herbicides, 0 otherwise			0.4149	0.4933
Bunding	Dummy=1 if household adopted bunding, 0 otherwise			0.1632	0.3700
Sell output	Dummy=1 if household sold rice output, 0 otherwise			0.6340	0.4823
		Min	**Max**	**Mean**	**Std. Dev**
Quantity Sold	Number of bags(96 kg/ bag) of output sold	0	571.2	10.5069	34.3683
Yield(Bags/Acre)	Number of bags (96 kg bag) harvested per acre	0.45	28.78	7.2954	4.7757
Proportion Sold	Proportion of harvest sold (ratio)	0	1	0.4121	0.3693

Source: Survey Data 2015

4.3 Adoption of improved rice production technologies

The adoption rates for the five rice production technologies was low. Each technology recorded less than 50 percent of farm households to have engaged in its continual usage for more than two years. Use of improved rice varieties recorded the highest adoption rate of 46.85 percent, chemical fertiliser (43.36 percent), herbicides (41.49 percent), planting by drilling or dibbling (37.30 percent) with the lowest adoption rate of 16.32 percent for bunding (see Figure 4.1).

The topmost adopted technology was the adoption of improved rice variety with 46.85 percent, the rate of adoption of improved rice varieties reflects the rate estimated at about 46 percent by Wiredu *et al.*, (2010) and 48 percent by Ragasa *et al.* (2013) in their study of smallholder rice farm households in Ghana. Bunding technology, a practise from the sawah system has prospects of increasing rice yield irrespective of variety and contributes to improvement in soil and water management (Buri, Issaka, Wakatsuki and Kawano, 2012), yet adoption rate is generally poor among farm households. Refer to figure 4.1 below

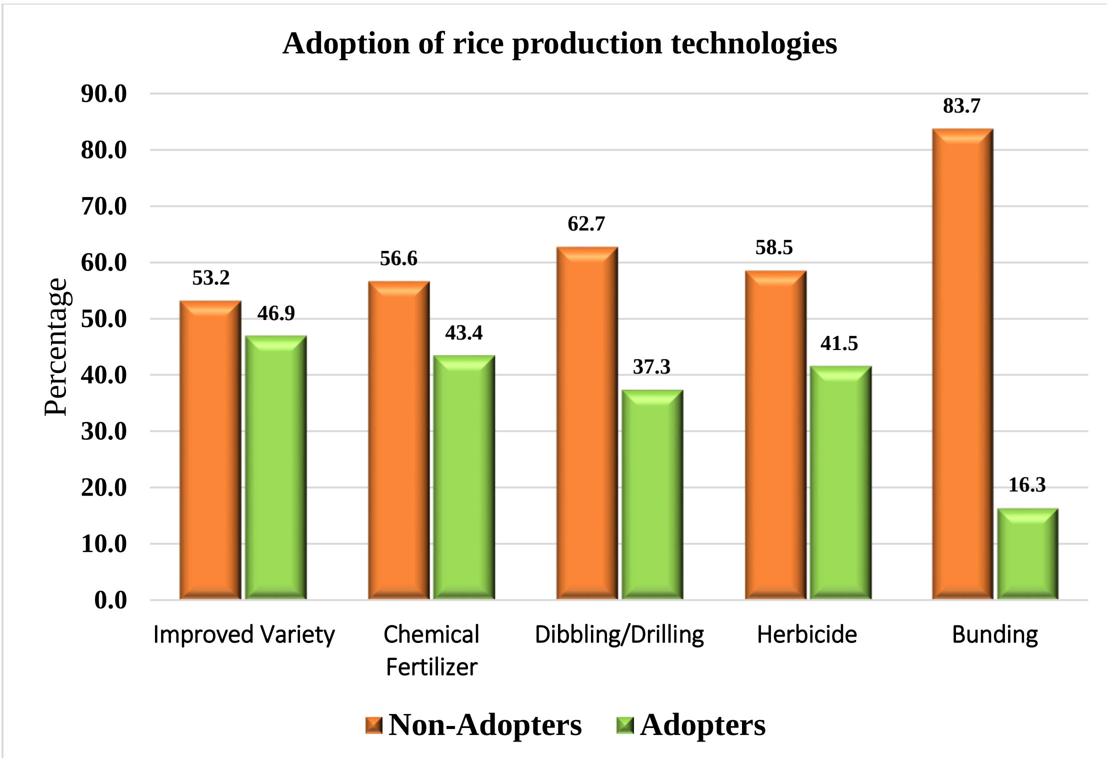


Figure 4. 1: Adoption of rice production technologies
Source: Survey Data, 2015

Adoption of improved rice varieties varied across the three regions surveyed. Farm households in Northern region topped in the use of improved rice varieties (61.06 percent) and herbicides (63.94 percent) but performed worst in the adoption of bunding (7.21 percent). With regard to the adoption of chemical fertiliser, bunding and planting by dibbling or drilling, farm households in the Upper East region outperformed the Northern and Upper West regions with adoption rates of 58.65 percent, 35.34 percent and 62.41 percent respectively. Adoption rates in the Upper West region was generally low with farm households recording less than 35 percent adoption across all the five rice production technologies. The low adoption rates recorded in the Upper West region is possibly because of the low population of rice farm households which is often characterised with low diffusion compared with the Upper East and Northern regions. Furthermore, though adoption of bunding was generally low, the Upper East region recorded a significant number of farm households who have embraced this technology, this may be due to the rising and falling nature of the topography which makes lands less leveled in the Upper East region compared with other regions. Farmers will therefore be more likely to construct bunds to conserve water and prevent it from running off due to the nature of the topography (see Table 4.4).

Table 4. 4: Adoption of improved rice production technologies across regions

Rice Technologies	Northern Region (208)		Upper East region (133)		Upper West Region (88)	
	Adopters	Non-Adopters	Adopters	Non-Adopters	Adopters	Non-Adopters
Improved varieties (%)	61.06	38.94	33.08	66.92	34.09	65.91
Chemical fertiliser (%)	44.23	55.77	58.65	41.35	18.18	81.82
Dibbling / drilling (%)	22.60	77.40	62.41	37.59	34.09	65.91
Herbicides (%)	63.94	36.06	18.05	81.95	23.86	76.14
Bunding (%)	7.21	92.79	35.34	64.66	9.09	90.91

Source: Survey Data 2015

4.4 Rice varieties cultivated by farm households

About twenty rice varieties have been released in Ghana since the early 1970's (CCVRRG, 2015). All the released varieties have been officially registered in Ghana. Most of the released varieties are from CSIR (SARI and CRI), International Rice Research Institute (IRRI), AfricaRice and other countries' research institutes. Earlier rice varieties released in Ghana were for low land ecologies while those released for upland ecologies only began in the year 2009.

Jasmine 85, also called Gbewa or lapez by farmers is the most common rice variety cultivated by farm households in northern Ghana as at the year 2015. Jasmine 85 cultivated by majority (26 percent) of farm households is officially registered as GBEWA RICE in Ghana. Jasmine 85 is a short maturity (110 - 115 days) aromatic rice suitable for both irrigated and rain fed lowland. Jasmine 85 is an improved variety released in Ghana in the year 2009 with yield potential of about 5 to 8 metric tons per hector, milling rate of 62 percent, aromatic long grain, very high consumer acceptability and good resistance to common pest and disease (CCVRRG, 2015; Ragasa *et al.*, 2013).

The second most common variety cultivated is Digang, an improved variety popularly called Aberikukugu or Abirikukugu by farm households. About 13.75 percent of farm households cultivated Digang in the 2015 season. Digang is also a short maturity (115 – 120 days) non-aromatic improved rice variety and was officially released in 2003 with yield potential of about 4.8 metric tons per hector, but specifically grown because it is adaptive to low input system, good for drought prone areas and flexible across ecologies (CCVRRG, 2015; Ragasa *et al.*, 2013).

The third most cultivated variety in the 2015 cropping season was Mandii. Mandii which is traced back to Sierra Leone as the originating source and introduced in Ghana by MoFA in the 1970's. Mandii is popularly known for its ability to withstand weeds and floods and equally suitable for low-input systems. Mandii is one of the many non-improved rice varieties popularly grown by rice farmers in northern Ghana but separate from the officially released ones (Ragasa *et al.*, 2013).

The forth most popular variety is Gomma, a non-improved and non-aromatic variety, followed by Tox (GR-21, GR-22, Sikamo), NERICA (1and 2) and GR-18 (Afife) all improved varieties. Additionally, other rice varieties (Bombas, Mr. Iddi, Paul, Mr. Moore, etc.) are also believed to be traditional varieties and were named after the persons (mostly extension agents) who introduced farmers to these varieties. Other early released varieties like FARO-15 among many are also still being cultivated by a small fraction of farm households in northern Ghana.

Table 4. 5: Popular rice varieties grown during the 2015 production season

Popular Varieties Grown in 2015	**All Regions** (429)	
	Frequency	Percent
Jasmine 85 (Gbewa, Lapez)	114	26.57
Digang (Aberikukogu)	59	13.75
Mandii	52	12.12
Gomma	25	5.83
Tox (GR-21, GR-22, Sikamo)	12	2.80
NERICA (1 & 2)	10	2.33
GR-18 (Afife)	10	2.33
Other (*Bombas, Anyofula, Bazolgu, Awusiri, Salmasaa, FARO-15, etc.*)	147	34.27

Source: Survey Data 2015

4.5 Rice yield across adopters and non-adopters of improved rice varieties

Majority (78.55 percent) of farm households harvested less than 10 bags per acre followed by 13.99 percent who harvested between 10 to 15 bags per acre. Only about 7.46 percent of households harvested above 15 bags per acre from their rice plots. Given that the potential yield of rice under rain fed is pegged at about 6 - 8 MT/ha (25 - 32 bags/acre) with a national average yield of 2.75 MT/ha (11.6 bags/acre), (MoFA, 2016). The yield of a greater proportion of rice farmers in northern Ghana is below the national average though rice technologies abound. Only a few rice producing households recorded yields slightly higher than the national average.

The average yield (96 kg bags per acre) recorded from sampled farm households in northern Ghana was 7.30 bags per acre. Average yield of adopters of improved varieties is 8.42 bags per acre compared with non-adopters is 5.59 bags per acre. Rice yield of the majority (61.77 percent) of farm households fell below recorded average yield (below 7.30 bags per acre) with non-adopters of improved varieties leading. Furthermore 30.77 percent of farm household attained from 7.30 to 15 bags per acre with majority of this yield contributed by adopters of improved varieties. A very small proportion of rice farm households recorded yields above 15 bags per acre though this was clearly dominated by adopters of improved rice varieties.

Table 4. 6: Rice yield across adopters and non-adopters of improved rice varieties

Yield (96kg bag/acre)	Adoption of Improved Varieties		
	Adopters	Non-Adopters	All
Average yield (bags)	8.42	5.59	7.30
Below 7.30 bags (%)	53.10	74.85	61.77
7.30 -15 bags (%)	37.60	20.47	30.77
Above 15 bags (%)	9.30	4.68	7.46

Source: Survey Data 2015

Average rice yield among adopters and non-adopters varied across regions. The Upper East region recorded the highest rice yield (8.74 bags per acre) from adopters of improved varieties while the Upper West region recorded a yield of 8.27 bags per acre. For non-adopters of improved rice varieties, the Northern region recorded the highest yield (6.17 bags per acre) with the Upper East region reporting the lowest yield of 4.85 bags per acre (see Figure 4.2).

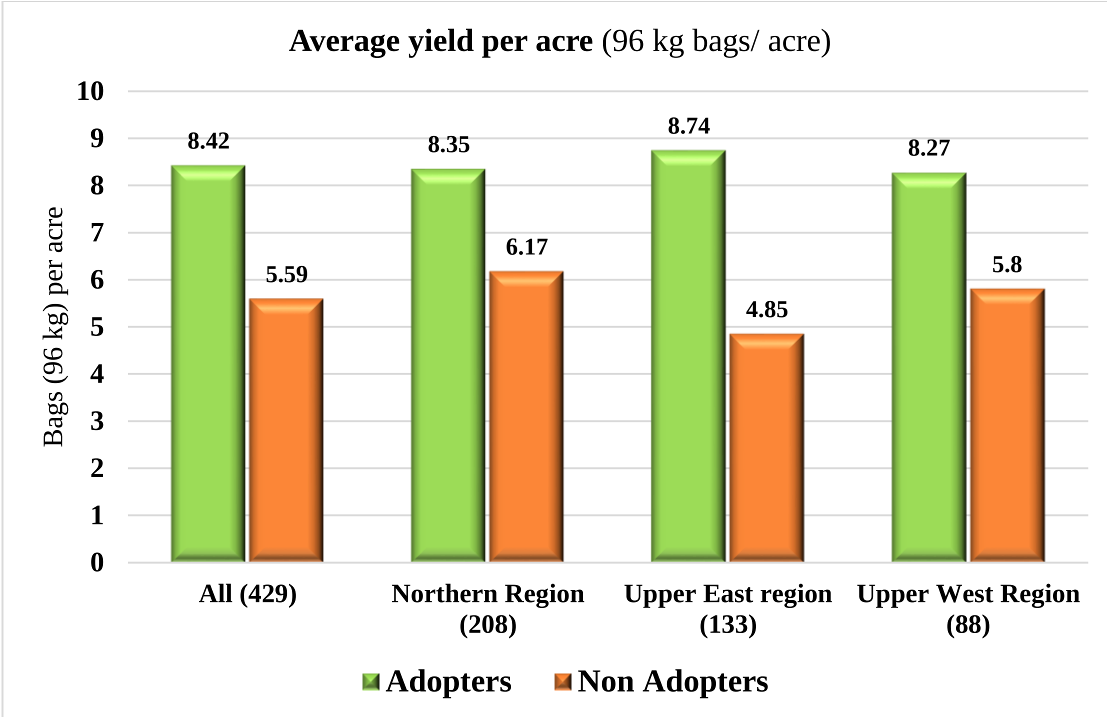


Figure 4. 2: Average yield of Adopters and Non-adopters across regions
Source: Survey Data 2015

4.6 Market participation

From Figure 4.3 below, about 63.40 percent of farm households participated in the rice output market. This implies that majority of farm households in northern Ghana sold rice output while a small proportion (36.6 percent) did not. Majority of farm households participated in the output market by selling more than halve of their rice output (see Figure 4.3 below). This reveals that rice is treated as a cash crop in northern Ghana, hence majority of farm households that produce rice are commercially oriented. These farm households produce rice primarily to generate income rather than for subsistence (consumption), they are more profit oriented given that their primary objective is to generate cash income (Ansah and Tetteh, 2016).

In addition, about 13.9 percent of farm households were found within the transitional zone (semi-subsistence) selling between 25 percent to 50 percent of their rice output. These category of farm households though concerned about food consumption, are also interested in earning some cash income from their rice output. Farm households that participated very low in the output market sold less than 25 percent of their output and represent 28.9 percent of sampled farm households. Farm households that sold less than 25 percent of their output are often labelled subsistence oriented farmers (Kostov and Davidova, 2012), households within this category are primarily concerned in meeting their food consumption needs (maximising the subsistence objective) rather than profit drive (see Figure 4.3).

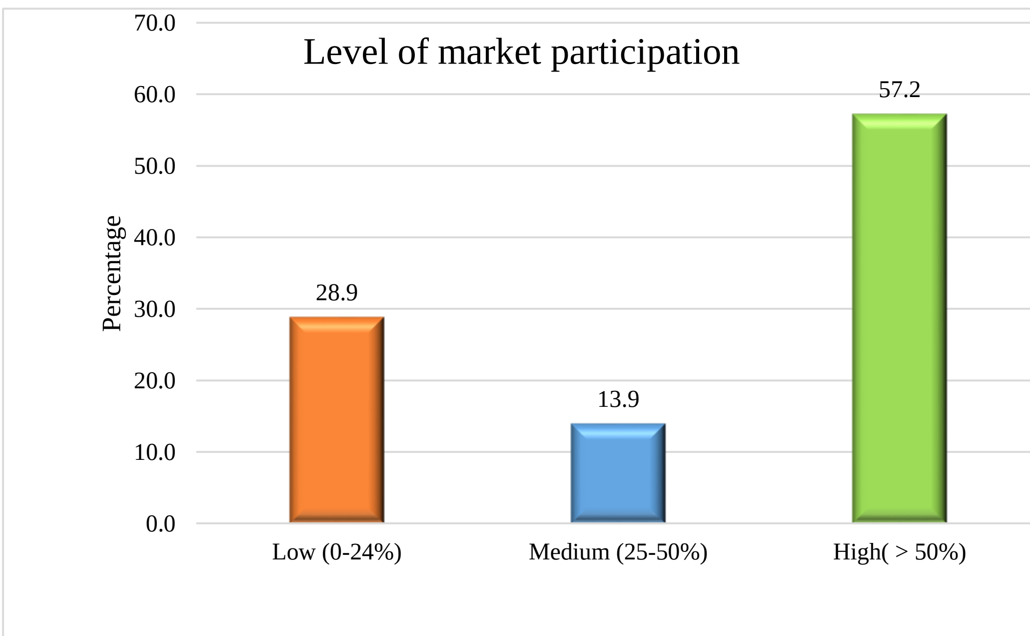


Figure 4. 3: Level of market participation
Source: Survey Data 2015

In Table 4.7, level of market participation varied across the three regions, a greater percentage (57 percent) of farm households in northern region were more commercially oriented selling more than 50 percent of their rice output whilst households (61 percent) in the upper west region cultivated rice with the goal of maximising their subsistence objective. The upper east region recorded a fair percentage of households participating very low and high in the output market.

Table 4. 7: Level of market participation across regions

Level of Market Participation	Northern Region (208)		Upper East region (133)		Upper West Region (88)	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Low (0-24%)	60	28.85	61	45.86	54	61.36
Moderate (25-50%)	29	13.94	14	10.53	16	18.18
High (> 50%)	119	57.21	58	43.61	18	20.45

Source: Survey Data 2015

4.7 Factors determining the adoption of improved rice production technologies

4.7.1 Pairwise correlations of rice production technologies

Pairwise correlations results of rice production technologies from the multivariate probit model are presented below in table 4.8. The likelihood ratio test (chi2 (10) = 178.52, p < 0.000) of the independence of the error terms of the improved rice production technologies is highly rejected. The alternative hypothesis of the mutual interdependence among the rice production technologies is accepted. The mutual interdependence among the use of improved varieties, chemical fertiliser, planting by drilling or dibbling, use of herbicides and bunding by rice producing farm households backs the use of multivariate probit model as equated to the use of independent probit models for predicting adoption of improved rice production technologies. The linear predictions from the Multivariate Probit model revealed that the probability of adopting Bunding is 33.64 percent, Herbicides (28.28 percent), Improved variety (26.49 percent), Dibbling or Drilling (31.68 percent) and Chemical fertiliser (25.39 percent). Results on the joint probabilities showed that the probability of success for adopting all the five technologies is 3.42 percent while the probability of not adopting any of the technologies is 20.28 percent. Detailed results from Stata output on the joint probabilities of success and failure, the linear predictions (Probability of adopting each of the technologies) and the marginal probabilities of each equation is presented in the appendix (see appendix A).

The joint interdependence among the rice production technologies point out that the likelihood of adopting any of the improved technologies is co-dependent on the decision of whether to adopt another technology or not. All pairwise coefficients of the correlation between the regression error terms are positive, indicating complementarity across the improved rice production technologies. Additionally, the correlation coefficients were statistically significant across the improved rice production technologies except for the use of improved varieties and bunding around plots.

First, we observed that adoption decisions exhibit strong complementarity between Fertiliser and Herbicides, Dibbling or drilling and Bunding, Improved varieties and Herbicides. Moderate complementarity between Fertiliser and Bunding, Fertiliser and Dibbling or drilling, Fertiliser and Improved varieties and, herbicides and bunding. Weak complementarity is observed between Dibbling or drilling and Herbicides and, Dibbling or drilling and improved varieties.

In table 4.8, use of chemical fertiliser is positively and significantly correlated with use of herbicides. The strong (60 percent) and statistically significant ($p < 0.01$) correlation between the use of chemical fertiliser and herbicides indicates that farmers who adopt chemical fertiliser also use herbicides for weed management. The results also show that adoption of soil fertility technology is most often combined with improved weed management technology. Farm households' use of herbicides reduce the amount of labour required to undertake manual weeding (hand weeding). Additionally, adoption of herbicides helps farmers to overcome labour shortage which often leads to late weeding and following an effect on the yield of rice due to weed competition. Adopting herbicides is a substitute to labour for manual weeding which does not only save cost and time, but by controlling weed with herbicides farm households will be more likely to invest in chemical fertiliser for an improvement in yield (Manda, 2011).

Farm households who adopt improved rice varieties combine it with herbicide application to control weed on their rice plots. The relationship revealed that adopting improved rice varieties is positively (53.60 percent) and significantly ($p < 0.01$) correlated with the application of herbicides on rice plots. Farm households who plant by dibbling or drilling coupled it with bunding around their rice plots. The results showed that planting by dibbling or drilling is positively (54.57 percent) and significantly ($p < 0.01$) related with bunding around rice plots. Refer to table 4.8.

Bunding around plots is positively (41 percent) correlated with chemical fertiliser application, indicating that farm household who bund around their plots are also more likely to adopt chemical fertiliser to improve plant nutrients. Additionally, the significant correlation coefficient value of 44 percent between fertiliser application and dibbling or drilling indicates that farm households who have embraced improved planting method by dibbling or drilling combine it with chemical fertiliser application. Refer to table 4.8.

Application of herbicides is positively (34.41 percent) correlated with bunding around plots, indicating that farm household who bund around their plots are also more likely to control weed via the application of chemical herbicides. The association between the use of improved rice varieties and chemical fertiliser application was also positive (34 percent) and significant ($p < 0.01$). The same applies for use of improved varieties and dibbling or drilling and, planting by dibbling or drilling in combination with the use of herbicides to control weed. All five rice technologies assessed complement each other and will jointly contribute to improving rice production among farm households. Refer to table 4.8.

Furthermore, it is not surprising that the correlation between improved varieties and dibbling or drilling was weak in addition to the non-significant correlation between the adoption of improved varieties and bunding. Adoption rates of the two technologies (bunding and dibbling or drilling) are wide apart from adoption rate of improved varieties revealing the possible concentration of interventions in additional to training and extension on rice technologies that are direct inputs (improved seeds, fertiliser and herbicides) as against more physical practises (bund construction and dibbling or drilling). Available expertise in bund construction and mechanised or manual service on bund construction is not widely available as compared with accessing direct inputs (improved seeds, fertiliser and herbicides). Tangible technical support on how rice farm households can adopt bunding and dibbling or drilling with ease is lagging behind and hence its practise is in a limited scale in Ghana (Ragasa *et al.*, 2013).

Table 4. 8: Correlation coefficients of the rice production technologies

Rice Production Technologies	Correlation Coefficient	Standard Error
Fertiliser and Bunding	0.4194***	0.0808
Fertiliser and Herbicides	0.6004***	0.0624
Fertiliser and Improved varieties	0.3472 ***	0 .0730
Fertiliser and Dibbling / drilling	0.4440***	0.0721
Dibbling / drilling and Bunding	0.5457***	0.0909
Dibbling / drilling and Herbicides	0.2014**	0.0865
Dibbling / drilling and Improved varieties	0.2205***	0.0842
Improved varieties and Bunding	0.1043	0.0935
Improved varieties and Herbicides	0.5360 ***	0.0865
Herbicides and Bunding	0.3441***	0.1089

Source: Multivariate probit model estimations, 2018

Joint Significance test of independent equations; chi2 (10) =178.52, Prob **> chi2** = 0.0000.

Significant levels;

***p < 0.01.

** p < 0.05.

* p < 0.10.

4.7.2 Factors that affect the adoption of rice production technologies

In table 4.9, the results on parametre estimates from the multivariate probit (MVP) regression for all the five rice production technologies assessed are presented. Individual variables related to farm households (family labour, salaried household head), farm and plot level characteristics (plot size, number of plots, plot ownership, soil fertility, years of usage, distance), institutional factors (training and extension) as well as economic characteristics (asset value and expenditure) are significant in informing adoption of rice production technologies.

Salaried household head

Farm households with salaried heads are more likely to adopt improved rice varieties and plant by dibbling or drilling. A salaried household head positively and significantly affects adoption of improved rice varieties (at 10 percent level) and plant by dibbling or drilling (at 5 percent level), (see Table 4.9). This means that salaried household heads have a higher probability of adopting improved rice varieties and plant by dibbling or drilling compared with non-salaried heads all things being equal.

The potential reason for this is that household heads in northern Ghana are those who make major decisions regarding agricultural production and resource allocation. Given that they earn income via receiving salary means that they can commit part of their income to purchase improved seeds and also finance labour intensive activities such as planting by dibbling or drilling which require much labour compared with the common practise of broadcasting rice.

Distance to rice parcel

Regarding distance to rice parcel, the estimated coefficient was statistically significant (at 10 percent level) and negatively influenced the probability of adopting improved varieties, chemical fertiliser and herbicides (see Table 4.9). The negative significant influence of distance to rice parcel on improved varieties, chemical fertiliser and herbicides means that longer distances decreases the probability of adopting improved varieties, chemical fertiliser and herbicides holding other factors constant.

Farm households often travel to distant rural settlements where they can have access to fertile rice plots for production. Additionally, virgin or newly cultivated plots are distant from the residential settlement of farm households. Given that distant farm lands are most often fertile with expected increase in output, possible explanations are that farmers will be less likely to adopt improved technology confident that a positive yield will be realised even without improved variety, chemical fertiliser and herbicides.

Number of rice plots

The results revealed that the coefficient of the number of rice plots owned by a farm household was significant (at 1 percent level) and positively affects adoption of herbicides and improved variety, but negatively affects the adoption of bunding (see Table 4.9). This means that holding other variables constant, more number of rice plots decreases the likelihood of raising bunds around rice plots but increases the probability of adopting herbicides and improved variety of rice.

If a farm household cultivates multiple rice plots then they are less likely to construct bunds around their plots, however the cultivation of multiple rice plots positively improves the probability of adopting herbicides. Construction of bunds around multiple rice plots will require a lot of labour hours or financial resource to hire a mechanised equipment which is also not readily accessible in rural areas. Additionally, weed control via manual weeding or hand pulling is labour intensive, time consuming and costly to undertake on multiple rice plots, given that farm households cultivate other crops they will be most likely to adopt herbicides which is time, labour and cost saving alternative to control weed. Farm households with multiple rice plots are likely to have more capacity to try or allocate a plot to cultivate improved rice variety. Multiple rice plots gives farm households higher ability to try out and adopt different rice varieties.

Number of crops

The negative significant sign of the coefficient of the number of crops cultivated at 1 percent level for the adoption of Herbicides and 5 percent level for the adoption of improved varieties (see table 4.9) means that, farm households who are engaged in the production of multiple agricultural crops are less likely to adopt herbicides and improved rice varieties all other things being equal. Farm households that have diversified their production are less likely to adopt herbicides and improved varieties on their rice plots unless in cases where rice production is the main agricultural crop or contributes substantially to household income. Also, if the farm household is engaged in the production of many crops then limited production resources will have to be allocated for the production of all crops. In addition, where there is specialisation and dependence on other crops, households that have built experience over time are most likely to invest resources and concentrate more on such crops.

Total family labour for rice

Similarly, in table 4.9, the coefficient of total family labour involved in rice production is positively related to the likelihood of adopting dibbling or drilling (at 1 percent level) and bunding around rice plots (at 5 percent level). The results reveal that total family labour involved in rice production increases the probability of adopting dibbling or drilling and bunding around rice plots, holding other variables constant.

Dibbling or drilling and bunding are labour intensive practises and availability of family labour reduces labour cost and serves as an incentive for farm households to adopt bunding and dibbling or drilling. Though bunding can be done via tractor service or manual labour, smallholders will prefer to use manual labour (family) which lowers cost.

Land ownership

Land ownership was a statistically significant factor influencing the probability of adopting bunding around rice plots (at 1 percent) and planting by dibbling or drilling (at 5 percent) if the plot where rice is cultivated is a family owned land (see Table 4.9). The positive significant influence of land ownership on the probability of adopting bunding and dibbling or drilling means that adoption of bunding and planting by dibbling or drilling is more likely if rice cultivation is undertaken on family plots compared with land accessed through other means (*rented, village chief, government, etc.),* holding other variables constant.

Size of rice plot

Size of rice plot was significant (at 1 percent level) and inversely influence the likelihood of adopting planting by dibbling or drilling (see Table 4.9). This means that holding other factors constant, an increase in the acreage cultivated by rice farm household decrease the probability of planting by dibbling or drilling. Dibbling or drilling is a labour intensive activity which hinges on the availability and access to family or hired labour compared with broadcasting which is faster and less costly. Additionally, given that rice valleys under rain fed production are easily flooded, households with large acreage will prefer to adopt a time saving planting method to avoid the possibility of not being able to plant.

However, access and timely availability of labour can sustain the likelihood of adopting dibbling or drilling but much labour activities in northern Ghana is primarily dependent on family labour and during the onset of rains labour access is scarce especially in farming communities since active persons will be focused on family or household agricultural activities.

Years of usage

Years of cultivating rice plot is positive and significantly (at 5 percent level) influences the probability of adopting improved rice varieties (see Table 4.9). Continual cultivation of rice plots over years increases the probability of uptake of improved rice varieties other things being equal. Farm households are likely to observe changes in yield as soil deteriorates over time and are therefore more probable to adopt improved rice varieties which are high yielding. Probability of adoption is low with initial cultivation of rice plots since farmers build experience over time through study and observation of plot characteristics. Farmers are therefore more likely to adopt improved technology when they have gathered information about plot characteristics over time than at early or trial stage of the plot. Understanding plot features reduces farm households risk in investing in improved technologies.

Construction of bunds around rice plots is more likely to be practised on family land compared with lands that are not owned by the farm household. Once bunds are constructed they can be maintained over two years and farm households will prefer to invest in bunding if they are sure of enjoying the full benefits of their investments. Farm households will therefore be less likely to invest in bund construction on rice plots that they have no ownership or less control. Family labour is likely to be easily accessible and nearer to rice plots owned by farm households compared with other means (*rented, village chief, government, etc.*) all things being equal and will therefore motivate farm households to adopt planting by dibbling or drilling given that there is accessible family labour. Additionally, some cost may be incurred for the use of rice plots if land is not owned by farm household and farmers will be less likely to adopt planting by dibbling which comes along with labour cost.

Training

Access to training on rice production significantly increases farm household's probability of adopting rice production technologies. Training service accessed from NGO's had a positive coefficient and was statistically significant in explaining the adoption of herbicides (at 5 percent level) and fertiliser (at 10 percent level). Also, training service accessed from Government institutions (MoFA, SARI) positively influenced the adoption of herbicides (at 1 percent level), adoption of improved varieties (at 5 percent level) and the adoption of fertiliser at 10 percent level of significance, (see Table 4.9). The positive significant sign on the coefficient of training implies that access to training on rice production from Government and NGO's increases farm households' probability of adopting herbicides, improved varieties and chemical fertiliser other things being equal.

This finding is consistent with the fact that training raises awareness of improved technologies, improves dissemination of rice production technologies and promotes learning of good agricultural practices (GAP) among farmers and will have a greater influence on the adoption decisions of farm households. Farm households that received training and extension service from government related institutions such as MoFA and SARI were more likely to adopt improved rice varieties, herbicides and chemical fertiliser to augment their production. These government institutions most often undertake field training and practical demonstrations either solely or in collaboration with development partners (agricultural programmes and projects) where they demonstrate to farmers the benefits of adopting improved rice technologies. This aligns with previous studies on technology adoption (Mwangi and Kariuki, 2015; Asante *et al.*, 2014; Bruce *et al.*, 2014).

Furthermore, training from non-governmental organisations was more probable to influence the adoption of herbicides and fertiliser. Adoption of improved varieties was skewed towards government institutions probably because these institutions are formally mandated to undertake breeding and dissemination of improved varieties.

Soil Type

Soil type was used as a proxy to ascertain the soil fertility of rice plots. The results revealed a positive significant sign (at 5 percent level) on the coefficient of clayey soil on the possibility of adopting chemical fertiliser (see Table 4.9). This implies that probability of adopting chemical fertiliser is higher if the soil type on rice plot is mainly clayey compared with other soil types, holding other factors constant.

Greater crop failure is more likely on soils with low fertility equated with rich fertile soils. Farm households are more likely to adopt chemical fertiliser application if the main soil type on their rice field is clayey which is often characterised with low fertility rate compared with other types of soils like loamy soil (Berazneva, McBride, Sheahan and Guerene, 2017). Farm household who cultivate rice on poor soils cannot realise good yield without investment in soil fertility management technologies, therefore farm households will be keen in investing in soil fertility enhancing inputs like fertiliser on soil types associated with low fertility.

Asset value

Regarding asset value, total value of assets was used as proxy for household wealth. The results revealed that the coefficient of total asset value was statistically significant and positively affects the probability of adopting bunding around plots (at 1 percent level) and adopting planting by dibbling or drilling (at 5 percent level), but negatively affects the adoption of herbicides at 1 percent level, (see Table 4.9). This implies that farm household's asset value positively and significantly increases the probability of adopting bunding around plots and planting by dibbling or drilling but decreases the probability of adopting chemical herbicides to control weed, holding other variables constant.

Wealthy farm households have the ability to invest in improved technology and the capacity to take the associated risk of adopting innovations (Ali and Erenstein, 2017). Wealthier farm households will therefore have the capacity to finance cost that are associated with labour and cost intensive practises like bund construction, dibbling or drilling and manual or hand weeding as against chemical weeding.

Alternatively, the negative association between asset value and adoption of herbicides did not meet the expectation of the study. It was expected that wealthier households will have the capacity to cultivate large acreage and will be more likely to adopt labour and cost saving weed management technologies like herbicides. The possible explanation for this results is that wealthier farm households can afford to finance manual weeding or hand pulling of weeds in addition to adopting chemical herbicides compared with non-wealthier farm households who may concentrate solely on herbicides to reduce cost.

Consumption Expenditure

Consumption expenditure is negative and significantly (at 1 percent level) influences the probability of adopting planting by drilling or dibbling (see Table 4.9). The results revealed that an increase in farm household consumption expenditure decreases the probability of adopting planting by drilling or dibbling, holding other factors constant. The negative effect of consumption expenditure on the probability of planting by drilling or dibbling did not meet the expectation of the study.

Given that about 44 percent of household members are dependents as against 56 percent active members coupled with a proportion of about 38 percent of members who are still in school indicates that a significant number of dependents may be driving consumption expenditure high with less or no contribution to household income and farm labour support. Consumption expenditure is expected to be high among households with larger members but this will not translate into more income and labour supply to promote adoption of labour and cost intensive technologies like dibbling or drilling if a significant proportion of members are dependents. In this scenario, higher consumption expenditure may be an indication of more pressure on the active members within smallholder farm households to meet household consumption expenditure with limited income and labour to adopt planting by dibbling or drilling.

Table 4 :tors that affect the adoption of rice production technologies (Multivariate probit regression output)

Indep Variables	**Use of Rice Production Technologies**									
	Bunding		**Herbicides**		**Improved varieties**		**Dibbling / drilling**		**Fertiliser**	
Proporti ve members	0.5391	(0.4259)	0.3063	(0.3383)	0.2526	(0 .3297)	0.4205	(0.3219)	-0.1528	(0.3151)
Salaried old head	-0.3763	(0.4173)	0.4293	(0.2942)	**0.5215***	(0.2745)	**0.6821****	(0.2831)	0.3120	(0.2598)
Size of r :el (acres)	-0.0389	(0.0289)	0.0183	(0.0238)	0.0102	(0.0224)	0.0228	(0.0234)	-0.0114	(0.0144)
Distance parcel (km)	-0.0103	(0.0136)	**-0.0179***	(0.0102)	**-0.0143***	(0.0079)	-0.0068	(0.0103)	**-0.0236***	(0.0126)
Number plots	**-0.3374*****	(0.1296)	**0.3801*****	(0.0997)	**0.3066*****	(0.0916)	0.0391	(0.0939)	0.1173	(0.0876)
Average rice plot (acres)	-0.0913	(0.0944)	0.0897	(0.0851)	0.0428	(0.0822)	**-0.2776*****	(0.0955)	0.0021	(0.0646)
Number s	-0.0315	(0.0894)	**-0.2870*****	(0.0752)	**-0.1341****	(0.0668)	-0.0379	(0.0696)	-0.0165	(0.0585)
Years of	0.0060	(0.0064)	-0.0081	(0.0057)	**0.0139 ****	(0.0055)	0.0042	(0.0056)	0.0003	(0.0057)
Total fai our for rice	**0.0027****	(0.0013)	0.0008	(0.0011)	0.0015	(0.0012)	**0.0034*****	(0.0011)	0.0001	(0.0009)
Land ov p										
C ip of plot	0.5534	(0.3631)	0.3119	(0 .2718)	-0.1940	(0.2481)	0.0557	(0.2742)	0.2898	(0.2385)
A l family plot	**0.9868*****	(0.3798)	-0.0819	(0.2899)	-0.0269	(0.2622)	**0.6358****	(0.2840)	0.2048	(0.2576)
Trainin										
Go (MoFA, SARI)	0.1244	(0.2015)	**0.4872*****	(0.1807)	**0.3173****	(0.1602)	-0.0728	(0.1801)	**0.2964***	(0.1686)
NC	0.3899	(0.2869)	**0.6070****	(0.2542)	0.0106	(0.2334)	-0.1057	(0.2563)	**0.3795***	(0.2287)
Soil Typ										
Cla	0.3154	(0.1952)	0.0116	(0.1486)	0.0787	(0.1434)	-0.0484	(0.1477)	**0.2884****	(0.1348)
Loa	0.2713	(0.1834)	-0.1827	(0.1522)	-0.0588	(0.1386)	-0.0812	(0.1474)	0.0961	(0.1389)
Consum xpenditure	0.0000022	(0.0000021)	0.0000017	(0.0000022)	-0.0000015	(0.0000021)	**-0.000018*****	(0.000007)	0.0000026	(0.0000019)
Asset value	**0.000029*****	(0.0000055)	**-0.000013*****	(0.000005)	-0.0000025	(0.0000046)	**0.000011****	(0.0000048)	0.0000071	(0.0000044)
Constant	*-1.6297****	*(0.5447)*	*-0.6334*	*(0.4363)*	*-0.7568 **	*(0.4072)*	*-0.2937*	*(0.4374)*	*-0.7811***	*(0.3668)*
Number of observations					429					
Wald chi2(85)					339.77					
Prob> chi2					0.0000					

Source: Multivariate probit model estimations, 2018. ***, **, ***** *Significant at 10%, 5% and 1% respectively. Standard errors in parentheses* (*brackets*)

4.8 Effect of Improved varieties on the yield of Rice

4.8.1 Determinants of adopting improved varieties

The logistic regression model was used to assess the conditional odds of adopting improved rice varieties given observed farm households characteristics where the dependent variable equals one if farm households allocated a greater proportion of acreage to the cultivation of improved variety in the 2015 cropping season and zero otherwise. Summary results of the logistic regression model is reported in the appendix (Appendix B). Farm households' choice of cultivating improved variety was significantly and positively determined by household heads decision on the type of seed to plant, proportion of active household members educated, number of salaried males, number of trainings attended, planting method, ownership of rice plot, total family labour engage in rice production, seeds accessed from extension agents and seeds accessed from agro input shops. A few of the factors influencing adoption of improved rice varieties are discussed below.

The coefficient of the proportion of active members (household members) educated was positive and significant at 5 percent level (see Appendix B). Proportion of active members educated positively induces the probability of adopting improved rice varieties, this implies that increase in the proportion of educated active members in a household is associated with a higher probability of adopting improved rice varieties, other things being equal.

Number of trainings attended by farmers that are related to rice production significantly increases farm household's probability of adopting improved rice varieties. Number of trainings attended had a positive coefficient and was statistically significant in explaining the adoption of improved rice varieties (at 10 percent level). Therefore, a farmer is more likely to adopt improved rice variety as the farmer attends more training sessions related to rice production. This finding is consistent with the fact that the number of training sessions attended by farmers raises awareness of improved technologies, improves dissemination of rice production technologies and promotes learning of good agricultural practises (GAP) among farmers and will have a greater influence on the adoption decisions of farm households since adoption of improved varieties are often promoted during training sessions. Also, results from the multivariate probit regression showed that training service accessed from Government institutions (MoFA, SARI) and NGO's positively influenced the adoption of improved varieties (see Appendix B) and also aligns with previous studies on technology adoption (Mwangi and Kariuki, 2015; Asante *et al.*, 2014).

Seeds accessed from extension agents and agro input shops was a statistically significant factor influencing the probability of adopting improved rice varieties (at 10 percent) (see Appendix B). The positive significant influence of seeds accessed from extension agents and agro input shops on the probability of adopting improved rice varieties means that adoption of improved rice varieties is more likely if rice seeds are sourced from extension agents and agro input shops compared with seeds accessed through other means (*open market, friends, relatives, etc.),* holding other variables constant.

4.8.2 Effect of Improved varieties on the yield of Rice

The average treatment effect on the treated (ATT) was estimated by employing two approaches; the multivariate distance matching method and the propensity score matching (particularly the kernel matching method) in other to compare the results. An important component of any propensity score analysis is examining whether the propensity scores estimated is balanced between adopters and non-adopters (adequately specified). Appropriate methods for assessing whether the propensity score model has been adequately specified involve examining whether the distribution of measured baseline characteristics is similar between adopters and non-adopters with the same estimated propensity score. Establishing whether the estimated propensity scores are balanced is very useful for determining the common area of support or the degree of overlap in the propensity score between adopters and non-adopters of improved varieties. Propensity score matching approach cannot fully account for selection bias or characteristics of farmers that could not be measured (unobservable characteristics). Farmer characteristics that could not be measured may simultaneously influence adoption of improved varieties as well as yield of rice. In such situations a hidden bias might arise that will affect the robustness of the matching estimators, this bias will limit the authenticity of the estimated effect of improved variety on yield. Rosenbaum sensitivity analysis is performed to examine the vulnerability of the estimated effect of adopting improved variety on the yield of rice. Post estimation tests, common support diagnostics and balancing statistics are reported in the appendix (Appendix A: density balancing; cumulative distribution box plot; Rosenbaum bounds sensitivity analysis for hidden Bias). Balancing property was satisfied based on characteristics of adopters and non-adopters and the study was not sensitive to any unobservable (hidden bias) that may undermine the estimated effect of cultivating improved varieties on the yield of rice.

Additionally, Regression adjustments was performed to minimise possible bias due to residual dissimilarities in measured (observed) baseline characteristics between adopters and non-adopters of improved rice varieties. Performing regression adjustments increases accuracy for continuous outcomes (in this study yield of rice) as well as improving the statistical power of the effect of improved variety on yield. Regression adjustments were made for quantity of fertiliser applied per acre (both first and second application), method of planting (dibbling, drilling, broadcasting), soil type (clay, loam, sandy, laterite, other), extension and training among others that may account for difference in yield.

In table 4.10, the results revealed that adoption of improved rice variety had a positive effect on yield of rice. Positive effect was realised for both the multivariate distance and propensity score matching approaches. For the multivariate distance method positive effect was realised at 1 percent significance level showing that the yield of farm households that adopted improved varieties is 2.85 bags (96 kg per bag) more than that of non-adopters for every acre of rice plot cultivated. The propensity score matching approach also revealed a 2.42 bags increase in yield per acre if farm households adopted improved varieties. Other studies (Bruce *et al.*, 2014; Wiredu *et al.*, 2010) on the adoption of improved rice varieties in northern Ghana confirmed that adoption contributes significantly to increased yield. The results showed that yield per acre of farm households that cultivate improved varieties was higher than households that cultivate non-improved rice varieties.

Table 4.10: Effect of Improved varieties on the yield of Rice

Methods		Observed Coefficient	Standard Error	P>|z|
Multivariate-distance Method (*With regression adjustments*)	ATE	2.67	0.51	0.000
	ATT	**2.85**	0.67	0.000
Propensity-score kernel matching	ATE	2.60	0.56	0.000
	ATT	2.42	0.59	0.000

Source: Multivariate-distance and Propensity-score estimations, 2018

4.9 Factors that affect the level of market participation

In table 4.11, the results of the quantile regression are reported. The coefficient of explanatory variables included in the model varies across different quantiles. Some variables only affect households that participate very low in the output market, whereas other factors are only significant at higher levels of output participation. The impact of farm household's characteristics on the level of market participation varies at different quantiles. The study focused on the differences in the estimated coefficients across different levels of market participation (quantiles). For this study, quantile regressions have been estimated at quartiles 0.25^{th}, 0.50^{th} and 0.75^{th}.

Higher quantiles indicate farm households that sell a higher portion of their rice output than other similar farm households and lower quantiles signify farm households who trade a lesser proportion of their output (Kostov and Davidova, 2012; Powell, 2011). That is, farm households that are more commercially oriented have higher aspiration to trade and will sell a higher proportion of their rice output relative to subsistence oriented farm households with similar features. The 0.75^{th} (restricted) quantile describes farm households that trade a greater proportion of their rice output than similar farm households and the 0.25^{th} quantile represents farm households that trade a lesser share of their rice output than similar farm households.

There are 14 explanatory variables out of 18 that significantly influenced the level of market participation (dependent variable). The results reflect a strong clustering of the effects of covariates at the middle and top quantiles (0.50^{th} and 0.75^{th}), that is for transitional (semi commercial) and market oriented (commercial) farm households. Majority (11) of the variables influenced the middle (0.50^{th}) quantile, ten (10) covariates influenced the topmost (0.75^{th}) quantile and four (4) variables influenced the lowest (0.25^{th}) quantile. Additionally, the direction of the effect of covariates did not change across quantiles for variables that were statistically significant in all quantiles, nevertheless the size of the coefficient varied.

The topmost (0.75^{th}) quantile was influenced by self-employed status of household head, number of rice plots, size of rice plot, proportion of household members in school, number of crops cultivated, decision on amount to keep (wife only), decision to sell rice (Husbands and wives, Husbands only) and Place of sale (Farm gate and big town market).

The middle (0.50^{th}) quantile was significantly influenced by self-employed status of household head, number of rice plots, size of rice plot, training, selling price (GH/kg), decision on amount to keep (Wife only), decision to sell rice (Husbands and wives, Husbands only) and place of sale (Village market and big town market).

The size of rice plot and place of sale variables (Farm gate, village market and big town market), were statistically significant in explaining level of participation in the lowest quantile. Apart from the positive sign of the coefficient of selling at farm gate which was significant at the topmost (0.75^{th}) quantile, all other explanatory variables met the expectation of the research.

In table 4.11, the size of farm household's rice plot influenced level of market participation in all the three quantiles. Size of rice plot was positive and statistically significant in the 0.25th quantile (at 1 percent level), in the 0.50th quantile (at 5 percent level) and in the 0.75th quantile (at 1 percent level). The expected effect of size of rice plot is positive, suggesting that larger farm size is related with more commercial orientation. The positive sign of the coefficient meets the *a priori* expectation of the study. Furthermore, larger farm size provides smallholder farm households a greater opportunity for surplus production (Musah, 2013). That is an increase in surplus production will translate into more participation even if their objective for undertaking rice production is to meet household consumption (subsistence oriented). Therefore, it is expected that the coefficients of farm size will be positive across all quantiles. This study supports the findings by Agwu *et al.*, 2012 and Martey *et al.*, 2012 who found that level of participation or commercialisation improves with increase in crop area. Farm households with lager acreage are more likely to be producing more output than what is required to meet subsistence needs (Mignouna *et al.*, 2015).

Sale of rice at big market (major metropolitan, municipal and district markets) positively influenced level of market participation in all quantiles. Selling at big market centers positively influenced participation in the 0.25th quantile (at 1 percent level), in the 0.50th quantile (at 1 percent level) and in the 0.75th quantile at 10 percent level of significance (see table 4.11). Big markets offers flexible opportunities for all farm households to trade with their rice output. The average price of selling in a big market is GH 1.37 per kilogram of rice paddy, which is higher than the price offered at farm gate (GH 1.094 per kg), village market (GH 1.30 per kg) and price offered by local traders and aggregators (GH 1.16 per kg). Good price at big markets offers an incentive for all categories of farm households to sell in big markets irrespective of their level of participation. Though the positive significance of selling in big town market at the lower (0.25th) contradicts the findings of Musah, 2013 and Martey *et al.,* 2012 in relation to extent of participation. They explained that transaction cost is incurred making it more costly and time consuming to travel to bigger market centers since farm households are rational to choose to sell more at farm-gate even though big market centers offer better opportunities.

However, majority of farmers (79 percent) rather sold a greater proportion of their output to local traders and aggregators and the least (2.3 percent) sold a greater proportion of their output at farm gate compared with big market (14 percent) and village market (4.7 percent). In this case farm households that sold output at farm gate explained that they did that because they needed immediate cash to pay for labour service during harvest and to service inputs they had accessed on credit for production, this was not the case of avoiding transaction cost. Additionally, farm households in communities that are close to big markets will incur less transaction cost in relation to time and transport cost and can choose to participate at different levels.

If differences in price between farm gate and markets can offset transaction cost and provide a much higher profit, then rational farm households will prefer to bear transaction cost in order to maximise profit compared with a lower profit with little or no transaction cost. Therefore, in big markets farm households are more likely to participate at any level.

On the other hand, given that price per kilogram of rice paddy is considerably higher in markets (big town markets and village markets) yet farm households (79 percent) sold a greater share of their output to local traders and aggregators. It can be explained that access to markets and transaction cost has a role to play in explaining why more output of rice is sold to local traders and aggregators. The positive sign however suggest that farmers who target big town markets are more commercial oriented though all category of farm households can equally participate.

Apart from the size of rice plot and selling at big market which affected all quantiles (0.25^{th}, 0.50^{th} and 0.75^{th}), all other variables affected some quantiles and not others. The interpretation below is structured by significant covariates across quantiles.

Selling at farm gate positively affects farm households' participation at the lower (0.25^{th}) and topmost (0.75^{th}) quantile at 5 percent level of significance. This shows that farm households who sell at farm gate are most likely to participate with 25 percent or less of their output or with 75 percent of output and more compared with sales to local traders and aggregators, other things being equal (see Table 4.11). The results imply that, selling at farm gate shapes the behaviour of subsistence oriented households to either participate very low (less than 25 percent of output) or participate very high (more than 75 percent of output) compared with selling to local traders and aggregators. Given that most farmers stated that they sold at farm gate because they needed immediate cash to pay for labour service during harvest and to service inputs they had accessed on credit for production, smallholder farmers may have to cover production cost immediately after harvest and the decision to participate low or high is then tied to how much immediate cash is needed to cover production cost. If cost of production is high, then subsistence oriented farmers will tend to participate highly (sell a greater proportion of their output) and behave as if they are market oriented but this is to cover production cost with the remaining output kept to meet consumption needs.

Selling at village market positively affects farm households' participation at the lower (0.25^{th}) and middle (0.50^{th}) quantile at 1 percent level of significance (see Table 4.11). This means that if a farm household choose to sell a proportion of rice paddy at the village market, it is more likely that the household will participate with about 50 percent or less of their output. Selling at village market shows a positive impact only at the lower (0.25^{th}) and middle (0.50^{th}) quantiles (i.e. for subsistence and semi-subsistence oriented farm households).

Number of rice plots had a positive impact at the middle and topmost quantiles. The coefficient of the number of rice plots cultivated by farm households was positive and statistically significant at 1 percent level in the middle quantile (0.50^{th}) and at 5 percent level at the topmost quantile (0.75^{th}), (see table 4.11). This implies that an increase in the number of rice plots cultivated increases the probability of participating with a greater proportion of output (with more than 50 percent and up to 75 percent or more of output).

In table 4.11, access to training on rice production, price of paddy (price per kg) and possession of a working radio set had significant and positive impact only on the middle (0.50^{th}) quantile at a 5 percent level of significance. Access to training has a positive association with technology adoption and adoption of improved technology positively contributes to output. Given that farm households have received training on rice production, they are more likely to increase output and participate more in the output market.

The coefficient of the selling price of rice paddy is positively related with the proportion of rice output sold implying that farm households who received higher prices have a higher probability of selling more (up to 50 percent of their output) compared with those who had relatively lower prices (see Table 4.11). This endorses the assertion that selling price is an inducement to supply more produce to the output market and confirms the findings of other studies (Olwande and Mathenge, 2012; Martey *et al.*, 2012) that reported a positive impact of selling price on participation and general market supply of output.

Possession of a working radio set improves access to market information particularly for farm households who mostly reside in rural areas. Farm households that have access to market information in the form of price and location are more likely to participate more than those who did not have access to market information (Musah, 2013). Public infrastructure and services like radio broadcast is found to positively influence market participation (Siziba *et al., 2011).* Besides, access to market information gives farm households more insights on market requirements and a window of opportunity to plan effectively given that they know the price and market requirements (Martey *et al.*, 2012), also, access to market information from formal sources like radio enhances the level of participation (Omiti *et al.,* 2009).

Farm household heads that were self-employed exerts a positive effect on participating at the middle (0.50^{th}) and topmost (0.75^{th}) quantile at 5 percent and 10 percent significant levels respectively (see table 4.11). A self-employed household head is defined as a household head who solely depends on agriculture as livelihood. The positive sign of the coefficient of self-employed heads at the middle and topmost quantile means, farm household heads that depend on their agricultural activities have a higher probability of participation with up to 50 percent and 75 percent or more of their output compared with household heads that combine agricultural activities with other non-agricultural activities.

In table 4.11, the results further revealed that there were no variations in the level of market participation if decision to sell was made by husbands (men) only or husbands and wives (men and women). The significant sign (at 5 percent level) of the coefficient if decision to sell rice paddy is made by Husbands and wives positively influence the likelihood of participating at the middle (0.50^{th}) and topmost (0.75^{th}) quantile. The coefficient of the decision to sell if decision is made by husbands only was significant (at 1 percent level) and positively related to the probability of selling at higher quantiles (0.50^{th} and 0.75^{th}). Decision making by husbands only or husbands and wives is collectively associated with higher probability of participating with a greater proportion of output, particularly output participation at the middle and topmost quantile compared with if decision to sell is made by others (*Children, wives only, all members*), holding other factors constant.

Regarding decision on amount of rice paddy to keep, the significant positive sign of the coefficient if decision on amount of rice paddy to keep is made by wives or women positively influenced the likelihood of participating in the middle (0.50^{th}) and topmost (0.75^{th}) quantile at 1 percent significance level. The results implies that, the possibility of selling up to 50 percent and more is higher if women take decision on the amount of rice paddy to keep for households need compared with if decision is made by others (*Children, Husband only, all members*), other things being equal (see Table 4.11).

Women and wives most often have good knowledge on the quantity of farm output that is needed to meet household consumption given that they play a major role in managing food staff and meals preparation within households. If decisions on the amount of rice paddy to keep is made by women, farm households are more probably to participate at higher quantiles.

Proportion of household members still in school and number of crops significantly influenced level of market participation only at the topmost (0.75th) quantile. The coefficient of the proportion of household members still in school was significant (at 10 percent level) and positive, meaning that an increase in the proportion of household members schooling will increase the probability of participating with up to 75 percent or more of rice output in the market, other factors held constant (see Table 4.11). Farm households are most likely to commercialise a greater proportion of output if the proportion of members in school increases.

Sale of farm output is one of the primary source of raising money to finance education within smallholder farm households. A greater proportion in school also means that there will be limited access to cheap family labour, less off-farm labour income with more weight placed on farm income to settle educational expenses. Limited access to family labour increase production cost, rise in production cost combined with educational expenses raises farm household's financial requirements which will increases the probability of selling more output to raise money.

Number of crops cultivated significantly (at 10 percent level) affects the probability of participating at the topmost quantile (0.75th) in a negative direction, which relate to farm households who cultivate many crops (see table 4.11). This means that holding other factors constant, farm households who cultivate many crops are less likely to sell a greater proportion of their rice output (up to 75 percent of their output) which met the expectation of the study. Farm households that cultivate diverse crops have flexible farm income sources compared with those that depend on few crops. Also, farm households that specialise in the production of single crops are more likely to sell a greater proportion of their output in order to cover other household needs.

In summary, size of rice plot and sales at big markets exerted a positive impact on all quantiles. Access to training on rice production, price of paddy (price per kilogram) and possession of working radio set had positive impact only on the middle (0.50^{th}) quantile while proportion of members in school and number of crops cultivated by a household had a positive and negative effect respectively and exclusively on the topmost (0.75^{th}) quantile. The remaining explanatory variables exerted a positive influence on two quantiles with much concentration of covariates (Number of rice plots, self-employed household head, decision to sell and decision on amount to keep) influencing both the middle (0.50^{th}) and topmost (0.75^{th}) quantiles. Sales at farm gate influenced participation at the lower (0.25^{th}) and topmost (0.75^{th}) quantile while sales at village market was significant at the lower (0.25^{th}) and middle (0.50^{th}) quantile.

Table 4. 11: Factors that affect the level of market participation (Quantile regression)

Independent Variables	Quantile =0.25		Quantile =0.50		Quantile =0.75	
	Coefficient	**Std. Err**	**Coefficient**	**Std. Err**	**Coefficient**	**Std. Err**
Self-employed household head	0.0121	(0.0170)	**0.1225****	(0.0618)	**0.1191***	(0.0646)
Salaried household head	-0.0090	(0.0596)	-0.0173	(0.1059)	-0.0840	(0.1147)
Number of rice plots	0.0183	(0.0258)	**0.0698*****	(0.0259)	**0.0615****	(0.0302)
Yield of rice	0.0012	(0.0044)	0.0052	(0.0053)	0.0003	(0.0053)
Size of rice plot	**0.0223*****	(0.0079)	**0.0159****	(0.0070)	**0.0189*****	(0.0059)
Proportion of hh schooling	- 0.0308	(0.0557)	-0.0731	(0.0806)	**0.1734***	(0.1030)
Training	0.0801	(0.0809)	**0.2338****	(0.0909)	0.0893	(0.0581)
Cultivate improved variety	- 0.0071	(0.0262)	-0.0138	(0.0578)	0.0258	(0.0524)
HH has radio	0.0235	(0.0151)	**0.0929****	(0.0464)	0.0270	(0.1007)
Selling Price (GH/kg)	0.0370	(0.0525)	**0.1388****	(0.0656)	0.0039	(0.0595)
Number of crops	-0 .0042	(0.0103)	-0.0265	(0.0188)	**-0.0362***	(0.0216)
Decision amount to keep						
Husband & wife	0.0095	(0.0239)	-0.0533	(0.0846)	-0.0358	(0.1367)
Wife only	0.0471	(0.1395)	**0.4388*****	(0.0897)	**0.4268*****	(0.1324)
Decision to sell rice						
Husband & wife	0.0196	(0.0411)	**0.1825****	(0.0832)	**0.2768****	(0.1249)
Husband only	0.0167	(0.0403)	**0.1550*****	(0.0546)	**0.3385*****	(0.1273)
Place of sale						
Farm gate	**0.3738****	(0.1475)	0.1697	(0.1195)	**0.2549****	(0.1121)
Village market	**0.3201*****	(0.0626)	**0.2038*****	(0.0619)	0.0359	(0.0914)
Big market	**0.4041 *****	(0.0949)	**0.2371*****	(0.0699)	**0.1334***	(0.0731)
Constant	-0.1193	(0.0843)	-0.2615**	(0.1054)	0.1209	(0.1532)
Pseudo R2	0.1157		0.2380		0.1477	
Number of observations			429			

Source: Quantile regression estimations, 2018. *, **, *** Significant at 10%, 5% and 1% respectively

4.10 Determinants of participation and intensity of participation in output markets

In table 4.12, the results of the probit model which estimates the first step for probability of participation in Heckman two step approach and the results of the Ordinary Least Squares (OLS) which estimates the intensity of participation are displayed. The Wald chi-square value of 469.93 is statistically significant at 1 percent indicating that the explanatory variables included in the model jointly explain the probability of participating in the rice output market.

The significance of mills lambda at 1 percent justifies the use of the Heckman two step model. The significance of mills lambda exposes the existence of selectivity bias in the model and if this was not fixed via Heckman two step approach, the predicted coefficients as well as the market participation variables, would have been bias. It would not have been possible to measure the true influence of the covariates on intensity of market participation among rice farm households.

4.10.1 Determinants of Market Participation

The choice of farm households to participate in the rice output market is statistically determined by 16 covariates out of 24. Precisely, number of crops cultivated, possession of a working radio set, possession of a mobile phone, household asset value, number of rice plots, yield per acre, average plot size, decision on amount to keep (if women decide), selling price (price per kilogram), decision to sell (men only; men and women), self-employed household heads, household receive remittances, cultivation of improved variety, proportion of rice output consumed and number of livestock (tropical livestock units) are the significant determinants of market participation. The significant variables determining the decision to participate in the rice output market are well distributed over the categorisation of the covariates; household characteristics, private assets, public assets and institutional factors.

In table 4.12, self-employed household head exerts a positive influence on the possibility of farm households participating in the rice output market and significant at 10 percent level. This means that farm household heads that depend solely on their agricultural activities have a higher probability of participating in the market compared with household heads that combine agricultural activities with other non-agricultural activities. Engagement in other non-agricultural activities and earning additional off-farm income is believed to initiate off-farm diversification which decreases farm household's likelihood of participating in the output market (Martey *et al.*, 2012).

The yield of rice is significantly associated with higher probability of participating in the output market at 5 percent level of significance (see Table 4.12). This means that improvement in yield increases the probability of participating in the output market, holding other factors constant. The positive sign of the coefficient meets the *a priori* expectation of the study since a higher yield per acre increases marketable surplus. Increase in rice yield enhances farm households chances of improving their income level from increased participation in the output market. This findings is also consisted with other works (Musah, 2013; Reyes, Donovan, Bernsten and Maredia, 2012).

Average farm size per household has a positive effect with a statistical significant influence (at 5 percent level) on the likelihood of participation in the output market (see table 4.12). The positive sign of the coefficient means that farm households with larger farm sizes have a higher probability to participate in the market. Additionally, farm households with large acreage of rice display a greater opportunity for extra production beyond household requirements (Mignouna *et al.*, 2015). The positive sign of farm size meets the *a priori* expectation as well as endorses findings of other authors (Mignouna *et al.*, 2015; Musah, 2013; Agwu *et al.*, 2012).

The coefficient of the selling price (price per kilogram) of rice paddy was positive and significant at 1 percent level (see Table 4.12). Price of rice paddy positively induces the probability of participating in the output market, this implies that increase in price per kilogram of paddy rice is associated with a higher probability of participating in the market, other things being equal. Farm households in the study area generally sold their rice paddy at different times and at different prices with some farm households selling a greater proportion of their output at relatively high prices. The results complements other studies (Musah, 2013; Martey *et al.*, 2012; Olwande and Mathenge, 2012) as well as endorses the statement from economic theory that, price is positively related to supply. Therefore, price of farm output motivates farmers to increase supply.

Cultivating improved rice variety has a positive effect on the probability of participating in the output market. Improved variety cultivation was statistically significant at 5 percent with a positive coefficient which met the expectation of the study (see Table 4.12). The results show that, holding other factors constant farm households that cultivated improved rice varieties have a higher probability of participating in the output market compared with other households. Across the three regions surveyed, farm households that cultivated improved varieties obtained higher yield of about 8.35 bags (96kg per bag) per acre compared with a yield of 6.17 bags per acre recorded for other farm households. Averagely, surveyed farm households that cultivate improved rice varieties harvest 2.9 bags (96kg per bag) more than non-adopters for every acre of rice produced. The effect of cultivating improved varieties significantly contributes to higher output which increases the likelihood of participating in the market. The findings of this study is consistent with other studies (Bruce *et al.,* 2014; Wiredu *et al.,* 2010) which established that adoption contributes significantly to increased yield and yield improvement subsequently increases the likelihood of participating in the output market (Reyes *et al.,* 2012).

Regarding farm household's ownership of radio and mobile phone, ownership of these communication devices had a positive and significant influence on the probability of participating in the output market. In table 4.12, ownership of a working radio set and mobile phone was statistically significant at 10 percent and 5 percent respectively. Ownership of a working radio set and mobile phone represent access to a communication asset and access to both formal and informal sources of market information. The positive signs of the coefficients met the *a priori* expectation of the study. This implies that farm households who own communication equipment's (Radio or mobile phone) have a higher probability of participating in the market. In Ghana, radio stations often broadcast agricultural information regarding crop varieties, good agricultural practises, weather, and output prices among others. Ownernership of a communication equipment (Radio or mobile phone) is a means of accessing market information which influence farm households marketing decisions (Musah, 2013), lowers transaction cost that will have been incurred via physical travel to make enquiries and negotiations (Zamasiya *et al.,* 2014), and reduces their risk perceptions (Siziba *et al.,* 2011). Therefore, farm households who own radio or mobile phone are more likely to have access to market information which can easily influence them to participate in the market compared with those without market information.

The coefficient of the number of livestock was significant (at 5 percent level) and affects participation in output market in a negative direction (see Table 4.12). Number of livestock owned by a household was converted to tropical livestock units (weighted based on livestock species). This means that other things being constant farm households who own a lot of livestock are less likely to participate in the output market compared with other households. This result is consistent with the findings of Jaleta, Gebremedhin and Hoekstra (2009). Their study pointed out that ownership of livestock by farm households negatively influence their participation in the crop output market for the reason that it diverts farm households into another source of income.

Regarding number of rice plots cultivated, the estimated coefficient was significant (at 1 percent level) and positive (see Table 4.12). The positive significant effect of the number of rice plots cultivated means that all other things held constant, farm households with more rice plots significantly increases their probability of participating in the market. Farm households with multiple rice plots is positively associated with larger farm size. Additionally, larger farm size positively affects the probability of participating in the output market since larger farm size offers more opportunity to produce beyond subsistence requirement (Mignouna *et al.*, 2015; Martey *et al.*, 2012).

Regarding household decision making, decision to sell rice was significant and positively related to output participation if decision to sell was made by either husbands only (at 1 percent level) or husbands and wives (at 5 percent level) compared with if decision was made by other members (*Children, Wives only, all*), (see Table 4.12). Holding all other variables constant, rice farm households are more likely to participate in the output market if decision to sell is made solely by husbands (men) or both husbands and wives (women) compared with other members.

Similarly, the coefficient of decision on the amount of rice to keep was positive and significantly (at 1 percent level) influenced probability of participating in the market if decision was made by wives (women) only compared with other members (*Children, Husband only, all*) other things being constant (see Table 4.12). This is expected because wives (women) play a key role in household food system, women are traditionally responsible for household nutrition and food preparation and their decision on amount of paddy to keep to meet household consumption is important.

Number of crops cultivated by farm households was a statistically significant factor explaining the likelihood of participating in the output market. The negative significant sign (at 5 percent level) on the coefficient of output participation shows that farm households that are diversified in crop productions (cultivates multiple crops) have a low probability of participation in the output market compared with other farm households all things being equal (see Table 4.12).

The results indicated that the proportion of harvest consumed is of significant importance in explaining the likelihood of participating in the rice output market. The negative significant sign (at 1 percent level) of the proportion of harvest consumed means that, an increase in consumption reduces the probability of participating in the market holding other factors constant (see Table 4.12). Farm households primarily undertake production either to meet household consumption or for sale, nevertheless the quantity consumed invariably reduces stock available for market if even the initial goal for undertaking production was commercially oriented.

Surprisingly, total current asset value of farm households was significant (at 5 percent) and negatively associated with the likelihood of participating in the output market (see Table 4.12). The negative sign of the coefficient did not meet the *a priori* expectation of the study. The results found that farm households with higher asset value are less likely to participate in the output market, holding all other variables constant. It is expected that farm households with high asset value will have the ability to expand farm size and adopt improved inputs and labour intensive technologies which will increase output and promote market participation. Many studies have stressed on the importance of assets in increasing household output and realising marketable surpluses which positively improve participation in crop output markets (Sebatta, Mugisha, Katungi, Kashaaru and Kyomugisha, 2014; Reyes *et al.*, 2012; Mather *et al.*, 2011). Possible explanation for the negative effect of the asset value is that, households with higher asset values may primarily be engaged in off-farm activities or are diversified and concentrates on other crops to raise income.

Remittance had a positive effect on participation at a 10 percent level of significance (see Table 4.12). Farm household that receive remittances have a high probability of participating in the market. The *a priori* expectation of the study did not have a definite direction for households that receive remittance. Possible explanation is that remittance will positively influence output participation if income from remittance is put in improved technology and other farm practises (Alene *et al.*, 2008), if not, output participation declines if income from remittance is invested in off-farm activities. This results corroborates the works of other authors (Barret, 2007; Poulton and Leavy, 2007; Reardon, Timmer, Barret and Berdegue, 2003) who explained that off-farm income in the form of remittance to farm households is required to purchase farm inputs to improve production particularly for smallholders who cannot generate enough income.

4.10.2 Factors that determine the intensity of participation in output markets

The results for the factors influencing the intensity of participation in output markets (estimated by Ordinary Least Squares in the second step of the Heckman model) are also displayed in Table 4.12. The intensity of farm household's participation in the rice output market is statistically determined by 5 out of 15 covariates. Size of rice plot, yield per acre, access to training, proportion of harvest consumed and number of livestock (tropical livestock units) significantly influence the intensity of market participation.

Proportion of harvest consumed negatively influence both the participation and intensity of participation results and was statistically significant at 1 percent and 5 percent respectively (see Table 4.13). The negative sign of the coefficient of the harvest proportion consumed indicate that an increase in the proportion of output consumed by farm households reduces the quantity of bags that will be offered for sale.

Size of rice plot had a positive effect on both the participation and intensity of participation model and was statistically significant at 5 percent and 1 percent respectively (see Table 4.12). The positive significant sign (at 1 percent level) on the coefficient of plot size in the intensity of participation model, means that an increase in farm households plot size (acreage) results in an increase in the number of bags sold at the output market. For every one (1) acre increase in plot size, intensity of participation will increase by about eight (8) bags (96 kg per bag). Gebremedhin and Hoekstra (2007) in their study examining cereal marketing and household market participation among rice and wheat farmers in Ethiopia revealed that farmers with larger plot size (acreage) tend to participate more in the output market because of their ability to produce larger output. Larger plot sizes therefore induces both participation and intensity of participation in the rice output market.

In table 4.12, yield per acre of rice had a positive effect on both the participation and intensity of participation model and was statistically significant at 5 percent and 1 percent respectively. The difference in the level of significance between participation (5 percent) and intensity of participation (1 percent) supports the findings of Komarek (2010), who found that yield is more significant on the intensity of market participation unlike on the choice to participate. The positive significant sign of the coefficient of yield (Bags/acre) of rice in the intensity of participation model, means that holding all other factors constant, for every increase in yield of rice produced, more bags of rice paddy would be sold. An increase in rice yield by one (1) bag per acre will increase intensity of participation by 2.6 bags (96kg per bag). This results is in line with other findings (Reyes *et al.*, 2012), that farmers who have greater yield have more surpluses they could sell.

Number of livestock which was converted to tropical livestock units had a negative effect on both the participation and intensity of participation model. Number of livestock owned by farm households was statistically significant at 5 percent in both participation and the intensity of participation results (see Table 4.12). Given that one tropical livestock unit denotes the feed requirement of a standard animal (dairy cow) of a certain live weight usually pegged at 250 kg (Mulisa, 2017). An increase in the tropical livestock unit by one

(1) will decrease the intensity of participating in the output market by about 1.2 bags (96 kg per bag), holding other factors constant. Though the negative relationship is in line with the findings of Jaleta *et al.* (2009) who found that quantity of crop output sold decreases with livestock ownership due to income diversification, it is contrary to the *a priori* expectation of this study. Expectations were that farm households with larger number of livestock can raise income via sale of livestock to support agricultural production through input adoption to increase yield or output which will transform into more participation.

Regarding access to training, the estimated coefficient was significant (at 10 percent level) and positively influenced only the intensity of participating in the output market (see table 4.12). Farm households that have received training on rice production have better understanding of improved rice production technologies such as improved rice varieties, good agricultural practises which in turn increases their likelihood of producing more. The *a priori* expectation of access to training was imagined to be positively related to the probability and intensity of output participation, yet access to training only had a significant effect on the intensity of output participation. Farm households that received training in rice production participated with about 7.6 bags (96kg per bag) more than other households. The results of this study supports the works of Siziba *et al.* (2011) who found that access to training had a positive effect on the intensity of market participation yet training did not influence the likelihood of market participation.

In summary self-employed household heads, yield of rice, average farm size per household, selling price (*price per kilogram*) of rice paddy, cultivation of improved rice variety, ownership of a radio set, ownership of a mobile phone, number of rice plots cultivated, decision to sell rice (*husbands only, husbands & wife*), decision on amount of rice to keep (*wife only*) and remittances had a positive impact on market participation while number of livestock owned (*tropical livestock units*), number of crops cultivated, proportion of harvest consumed and total current asset value had a negative effect on market participation. Intensity of participation in output markets was positively influenced by average farm size per household, yield of rice and access to training but negatively influenced by proportion of harvest consumed and the number of livestock owned (*tropical livestock units*). Average farm size per household, yield of rice, proportion of harvest consumed and number of livestock owned (*tropical livestock units*) significantly influenced both participation and intensity of participation models.

Table 4. 12: Determinants of participation and intensity of participation

Explanatory Variables	Participation in Market (Probit Regression)		Intensity of Participation (Ordinary Least Squares)	
	Coefficient	**Std. Error**	**Coefficient**	**Std. Error**
Age household head	0.0019	(0.0070)	-0.1149	(0.1264)
Basic education household head	0.0396	(0.3297)	-5.1544	(6.2508)
Self-employed household head	**0.3863***	(0.1991)	1.2213	(3.8492)
Number of household members	0.0273	(0.0239)	-0.5565	(0.3420)
Proportion of active members	-0.5733	(0.4540)	-11.0659	(9.0542)
Proportion of members in school	-0.3576	(0.3695)	1.9901	(7.2209)
Number of crops	**-0.1404****	(0.0652)	-1.1373	(1.4106)
Number of rice plots	**0.3609*****	(0.1191)	2.2611	(2.6577)
Size of rice plot (average)	**0.1400****	(0.0576)	**8.3772*****	(0.4424)
Yield (Bags/acre)	**0.0434****	(0.0212)	**2.6121*****	(0.3726)
Selling Price (GH/kg)	**1.0350*****	(0.2759)	2.4127	(5.7622)
Training	0.3567	(0.2327)	**7.6753***	(4.2125)
Cultivate improved variety	**0.3724****	(0.1864)	6.2704	(3.8122)
Proportion of harvest consumed	**-2.7800*****	(0.3231)	**-35.7070 ****	(13.8222)
Household receive remittances	**0.7449***	(0.4050)	2.9344	(7.0808)
Current asset value of household	**-0.1220****	(0.0494)	-0.1918	(1.0077)
Tropical livestock units	**-0.0433****	(0.0189)	**-1.1896****	(0.4994)
Total consumption expenditure	0.0000021	(0.0000028)	0.00002	(0.00005)
Household own phone	**0.4354****	(0.2105)	2.7438	(4.5888)
Household own radio	**0.3772***	(0.2300)	1.5023	(4.5198)
Decision to sell rice				
Husband & wife	**0.9000****	(0.4111)		
Husband only	**0.6821*****	(0.2363)		
Decision amount to keep				
Husband & wife	-0.0330	(0.4094)	7.7943	(5.8029)
Wife only	**0.8292*****	(0.3184)	4.3718	(5.1107)
Constant	*-1.2717**	*(0.7183)*	*-27.965**	*(15.5659)*
Mills lambda	24.2563***	(8.4966)		
Rho	0.9120			
sigma	26.5964			
Number of observation			429	
Censored			157	
Uncensored			272	
Wald chi2(21)			469.93	
Prob > chi2			0.0000	

Source: Heckman model estimations, 2018. *, **, *** Significant at 10%, 5% and 1% respectively

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Chapter Outline

This chapter contains the summary, conclusions and recommendations deduced from the analyses and discussions of results in the preceding chapters. It presents the summary of the study (section 5.2), major findings of the study (section 5.3), conclusions (5.4), policy recommendations (section 5.5) and suggestions for future studies (section 5.6).

5.2 Summary of study

In Ghana, rice is an important staple food for both urban and rural population and competes effectively with traditional coarse grains. The bulk of domestic rice production come from Northern Ghana which covers the majority of rice cultivated area and considered the food basket zone of the country. However over the years, Northern Ghana has recorded a decline in their contribution to national rice production.

The general objective of this study was to examine agricultural technology adoption and market participation among smallholder rice farmers in Northern Ghana. The study evaluated factors that affect the adoption of improved rice production technologies and the effect of using improved varieties on the yield of rice. Also, factors that affect the level of market participation and the intensity of smallholder farmer’s participation in output markets was assessed.

The study sourced secondary data from the USAID Core of Excellence project from SARI, a subsidiary of the Council for Scientific and Industrial Research (CSIR), Ghana. A sample size of 429 rice farm households from northern Ghana (Northern, Upper East and Upper West region) was used for the study. The theoretical framework of technology adoption and market participation was modelled in a random utility framework. Specifically, theoretical framework of technology adoption under partial population exposure was employed for adoption.

Descriptive statistics was employed to describe rice producing households, adoption rates of rice production technologies among smallholder farm households and their participation in the output market. Factors that affect the adoption of improved rice production technologies was assessed using the multivariate probit model. The treatment effect appraisal (Multivariate Distance Matching) method was used to evaluate the effect of using improved varieties on the yield of rice. The level of market participation and the intensity of participation were analysed using Quantile regression and Heckman two-step model respectively.

5.3 Major findings of the study

- **Objective one**

The first objective of the study was to evaluate factors that affect the adoption of improved rice production technologies.

- Adoption of rice production technologies was generally low though adoption varied significantly across regions. Adoption of improved rice varieties recorded the highest rate followed by chemical fertiliser, herbicides, dibbling or drilling and the least was bunding.
- The study realised a positive correlation between rice production technologies showing complementarity between rice production technologies. Strong correlation was observed between the adoption of fertiliser and herbicides, followed by the correlation between the adoption of dibbling or drilling and bunding then the correlation between the adoption of improved varieties and herbicides.
- The linear prediction results revealed low probability values for adopting individual technologies. Results on the joint probabilities showed that the probability of success for adopting all the five technologies was very low compared with the probability of not adopting any of the technologies.
- Using the multivariate probit model, it was revealed that total family labour, land ownership and asset value were significant and positively associated to the likelihood of adopting bunding whereas number of rice plots negatively influenced bunding.
- Probability of adopting herbicides was positively influenced by number of rice plots and training (by government institutions and NGO's) but negatively influenced by number of crops, distance to rice parcel and asset value.
- In the improved variety equation, salaried household heads, number of rice plots, years of cultivation and training service by government institutions were positively related to the probability of adopting whilst the coefficient of the number of crops

cultivated and distance to rice parcel had a negative but significant effect on likelihood of adopting improved rice varieties.

- The likelihood of planting by dibbling or drilling was positively influenced by salaried household head, total family labour for rice, land ownership and asset value but negatively influenced by size of rice plot and consumption expenditure.
- In the fertiliser equation, the results showed that the coefficient of training service (by government institutions and NGO's) and soil type (clayey soil) were significant and positively associated with the probability of adopting fertiliser whereas distance to rice parcel had a negative effect on fertiliser adoption.

➢ **Objective two**

The second objective of the study was to assess the effect of using improved varieties on the yield of rice.

- The two top most popular rice varieties cultivated by rain fed farm households in northern Ghana are Jasmine 85 and Digang (Abirikukogu) which are improved varieties, however the third and fourth most popular rice varieties cultivated were non-improved varieties (Mandii and Gomma).
- The average yield of rice was 7.30 bags (96kg per bag) per acre but adopters of improved varieties recorded an average of 8.42 bags per acre whilst non-adopters recorded an average of 5.59 bags per acre.

- The Multivariate Distance Matching model revealed that adopters of improved rice varieties harvested 2.85 bags (96kg per bag) more compared with non-adopters for every acre of rice cultivated.

- **Objective three**

The third objective of the study was to estimate the level of market participation and determine the intensity of smallholder farmer's participation in output markets.

- On the average 63 percent of rice output is sold in northern Ghana within a production season. About 57 percent, 14 percent and 29 percent of rice producing households are characterised as high, medium and low commercial households. This shows that generally, rice farm households in northern Ghana are commercially oriented with majority selling their output to local traders and aggregators.
- The decision to participate in the rice output market is significantly determined by number of crops cultivated, number of rice plots, size of rice plot, yield, selling price, improved variety, off-farm income (remittances), asset value, household consumption, communication assets (Mobile phone and radio set), number of livestock owned (Tropical livestock unit), decision to sell (Husband only and, husbands and wives) and decision on amount to sell (Wives only).
- The likelihood of participating in the rice output market with a lower proportion (up to 25 percent) of total harvest is positively and statistically influenced by size of rice plot and place of sale (Farm gate, village market and big market).

- The choice to participate in the rice output market with up to 50 percent of total harvest is positively determined by self-employed household head, number of rice plots, size of rice plot, training, access to working radio set, selling price, decision to sell (Husbands only and, husbands and wives), decision on amount to sell (Wives only) and place of sale (Village market and big market).
- The choice to participate highly in the rice output market with up to 75 percent of total harvest is positively determined by the proportion of household members in school, self-employed household head, number of rice plots, size of rice plot, decision to sell (Husbands only and, husbands and wives), decision on amount to sell (Wives only) and place of sale (Farm gate and big market), but negatively related to the number of crops cultivated.
- The intensity of participation in the rice output market is positively determined by size of rice plot, yield, and access to training in rice production and negatively influenced by household consumption and number of livestock owned (Tropical livestock unit).

5.4 Conclusions

The following conclusions are drawn from the major findings of this study.

- The study provides an evidence of complementarity of rice technologies and low technology adoption among rain fed rice producing households. In all, majority of farm households adopted improved rice varieties compared with other technologies (chemical fertiliser, herbicides, dibbling or drilling and bunding). Adoption of rice production technologies is strongly influenced by both internal and external factors like household's characteristics, farm and plot level factors and institutional factors.

- Average yield of rice among rain fed households is generally low. Adoption of improved rice varieties contributes significantly to higher yields and an improvement in output market participation hence income growth. However, Mandii and other traditional rice varieties are still being cultivated by rain fed farm households in northern Ghana.
- Rice has gained the status of a cash crop with a majority of households participating and selling a greater proportion of their rice output. The study concludes that market participation is high, both market participation and intensity of participation are influenced by farm household's characteristics, farm and plot level factors, transaction cost factors and institutional factors. Size of rice plot, cultivation of improved variety, yield per acre, selling price and access to training on rice production are key variables that influence output market behaviour of rain fed rice farm households.

5.5 Policy Recommendations

- The complementarity observed among the rice technologies and the very low joint probability of success of adopting all five technologies suggest that extension information and farmer training should be designed to encourage rice farmers to think holistically in terms of adopting optimal combinations of rice technologies.
- The fertiliser subsidy programme should be strengthened by effectively targeting smallholders and expanded to include other complementary technologies and practises by ensuring that farmers in the programme adopt improved planting method and water management technologies such as bunding.

- Government and research institutions particularly the Plant Protection and Regulatory Services (PPRS) of MoFA, Crops Research Institute (CRI) and Savanna Agricultural Research Institute (SARI) of CSIR should consider long term policy of investing in the development of low input, drought and weed tolerant rice varieties to enhance the adoption of improved rice varieties among rain fed smallholder farmers in northern Ghana.
- Based on the findings that yield, training on rice production, selling price, cultivation of improved varieties, number of rice plots cultivated, size of rice plot, communication assets (Mobile phone and radio set) and number of livestock owned (Tropical livestock unit) are key variables that influence output market behaviour. We recommend that government and research institutions should promote extension and training to stimulate adoption of improved technology. The study advice farmers to participate in training and extension services to enhance their capacity to adopt rice technologies and particularly improved rice varieties which translates into higher yields.
- The National Food Buffer Stock Company (NAFCO) should intensify an effective buffer stock management system necessary to establish guarantee prices for smallholders particularly at the peak of the harvesting season when prices are low.
- Majority of rice farm households sell their output to local traders and aggregators at lower prices compared with what is offered at markets, the study recommends that the Metropolitan, Municipal and District Assemblies (MMDA) should invest in the development of a major market in each province and road network to reduce travel time and cost to encourage farmers to participate in markets.

5.6 Suggestions for future studies

The study recommends that future research should look at improved technology adoption and risk among irrigated and rain fed rice farmers. Studies on market participation should also look at both input and output participation of farmers simultaneously over time.

REFFERENCES

Abate, G. T., Francesconi, G. N., and Getnet, K. (2013). Impact of agricultural cooperatives on smallholders' technical efficiency: evidence from Ethiopia. *Euricse Working Paper number* 50(13).

Abdullah, R.F., Ahamad, R., Ali, S., Chandio, A. A., Waqar, A., Ilyas A., and Din, I. U. (2017). Determinants of commercialisation and its impact on the welfare of smallholder rice farmers by using Heckman's two-stage approach. *Journal of the Saudi Society of Agricultural Sciences.*

Abid, M., Scheffran, J., Schneider, U. A., and Ashfaq, M. (2015). Farmers' perceptions of and adaptation strategies to climate change and their determinants: the case of Punjab province, Pakistan. *Earth System Dynamics*, 6(1), 225-243.

Adebiyi, S., and Okunlola, J. (2010). Factors affecting Adoption of Cocoa Rehabilitation Techniques in Oyo State of Nigeria; Proceedings of the 18TH Annual Congress of the Nigerian Rural Sociological Association of Nigeria. FUTA. Akure, Nigeria.

Adegbola, P., and Gardebroek, C. (2007). The Effect of Information Sources on Technology.

Adesina, A. A. (1996). Factors affecting the adoption of fertilisers by rice farmers in Cote d'Ivoire. *Nutrient Cycling Agroecosystems*, 46(1), 29–39.

Adesina, A. A., and Seidi, S. (1995). Farmers' perceptions and adoption of new agricultural technology: analysis of modern mangrove rice varieties in Guinea Bissau. *Journal of International Agriculture*, 34(4):358-371.

Adesina, A., and Zinnah, M. (1993). Technology characteristics, farmers' perceptions and adoption decisions: a Tobit model analysis in Sierra Leone. *Agricultural Economics*, 9(4), 297-311.

Aggrey-Fynn, E. (1999). The Rice Sector in Ghana: A Case Study. Accra FAO office.

Agwu, N. M., Anyanwu-Andand, C. I., and Mendie, E. I. (2012). Socio-Economic Determinants of Commercialisation among Small Holder Farmers in Abia State, Nigeria. *Greener Journal of Agricultural Sciences*, 2(8), 392-397.

Akudugu, M. A., Guo, E., and Dadzie, S. (2012). Adoption of Modern Agricultural Production Technologies by Farm Households in Ghana: What Factors Influence their Decisions? *Journal of Biology, Agriculture and Healthcare* 2(3).

Akudugu, M. A., Nyamadi, B. V., and Dittoh, S. (2016). Transforming smallholder agriculture in Africa through irrigation: an assessment of irrigation impact pathways in Ghana. Invited paper presented at the 5th International Conference of the African Association of Agricultural Economists, September 23-26, 2016, Addis Ababa, Ethiopia.

Alene, A. D., Manyong, V., Omanya, G., Mignouna, H., Bokanga, M., and Odhiambo, G. (2008). Smallholder market participation under transactions costs: Maize supply and fertiliser demand in Kenya. *Food Policy*, 33 (4), 318–328.

Al-hassan, S., Sarpong, D. B., and Al-Hassan, R. (2004). Allocative efficiency, employment and rice production risk: An analysis of small holder paddy farms in the Upper East Region of Ghana. *Ghana Journal of Development Studies,* 64(1), 73–94.

Ali, A., and Erenstein, O. (2017). Assessing farmer use of climate change adaptation practises and impacts on food security and poverty in Pakistan. *Climate Risk Management*, 16, 183–194.

Amanor-Boadu, V., (2012). Rice Price Trends in Ghana (2006–2011). METSS-Ghana Research and Issue Paper Series No. 02-2012. Accra, Ghana: Monitoring, valuation and Technical Support Services (METSS), United States Agency for International Development (USAID).

Ana, R., William, R., Masters, A., and Shively, G. E. (2008). Linkages between market participation and productivity: results from a multi-country farm household sample. A paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Orlando, FL, July 27-29, 2008.

Ansah, I. G. K., and Tetteh, B. K. D. (2016). Determinants of Yam Postharvest Management in the Zabzugu district of Northern Ghana. Advances in Agriculture. *Advances in Agriculture, 2016.*

Arias, P., Hallam, D., Krivonos, E., and Morrison, J. (2013). Smallholder Integration in Changing Food Markets. Rome, Food and Agriculture Organisation (FAO) of the United Nations. Retrieved 01 August 2018, from http://www.fao.org/docrep/018/i3292e/i3292e.pdf

Asante, B. O., Wiredu, A. N., Martey, E., Sarpong, D. B., and Mensah-Bonsu. A. (2014). NERICA Adoption and Impacts on Technical Efficiency of Rice Producing Households in Ghana: Implications for Research and Development. *American Journal of Experimental Agriculture*, 4(3), 244-262.

Asfaw, S., Di Battista, F., and Lipper, L. (2016). Agricultural technology adoption under climate change in the Sahel: Micro-evidence from Niger. *Journal of African Economies*, 25 (5), 637–669.

Asfaw, S., Shiferaw, B., Simtowe, F., and Lipper, L., (2012). Impact of modern agricultural technologies on smallholder welfare: Evidence from Tanzania and Ethiopia. *Food Policy*, 37(3), 283–295.

Asteriou, D., and Hall, S.G. (2007). Applied Econometrics – a modern approach. Palgrave MacMillan.

Asuming-Brempong, S., Al-Hassan, R. M., Sarpong, D. B., George, T. M. K., Akoena, S. K. K., Owuraku, S. D., Mensah-Bonsu, A., Amegashie, D. P. K., Egyir, I., and Steve, A. (2004). Poverty and Social Impact Analysis (PSIA) Studies for Ghana: Economic Transformation of the Agricultural Sector. Final Report submitted to the National Development Planning Commission (NDPC)/ Ministry of Food and Agriculture (MoFA), and DFID, Ghana, for the "Economic Transformation of the Agriculture" Sector Study.

Asuming-Brempong, S., and Osei-Asare, Y.B. (2007). Has imported rice crowded-out domestic rice production in Ghana? What has been the role of policy? African Association of Agricultural Economists (AAAE) Conference proceedings, 2007; 91-97.

Awotide, B.A., Diagne, A., Wiredu, A.N., and Ojehomon, V.E., (2012). Wealth status and agricultural technology adoption among smallholder rice farmers in Nigeria. *OIDA International Journal of Sustainable Development,* 5 (2), 97–108.

Banerjee, B., Martin, S., Roberts, R., Larkin, S., Larson, J., Paxton, K., English, B., Marra, M., and Reeves, J. (2008). A Binary logit estimation of factors affecting adoption of GPS guidance systems by cotton producers. *Journal of agricultural and applied economics*, 40(1), 345-355.

Barret, C.B. (2007). Smallholder Market Participation: Concepts and Evidence from Eastern and Southern Africa. *Food Policy*, 33(4), 299-317.

Barrett, C. B. (2007). Smallholder Market Participation: Concepts and Evidence from Eastern and Southern Africa. *Food Policy*, 33(2008), 299–317.

Becker, S., and Ichino, A. (2002). Estimation of average treatment effects based on propensity scores. *Stata Journal*, 2(4), 358-377.

Berazneva, J., McBride, L., Sheahan, M., and Guerene, D. (2017). Empirical Assessment of Subjective and objective soil fertility metrics in East Africa: implications for Researchers and Policy makers. *World Development*, 105 (2018), 367-382.

Bernard, T., Taffesse, A.S., and Gabre-Madhin, E. (2008). Impact of cooperatives on smallholders' commercialisation behaviour: evidence from Ethiopia. *Journal of Agricultural Economics*, 39 (2), 147–161.

Besley, T., and Case, A. (1993). Modeling Technology Adoption in Developing Countries. *American Economic Review,* 83(2), 396-402.

Bisanda, S., Mwangi, W., Verkuijl, H., Moshi, A.J., and Anadajayasekeram, P. (1998). Adoption of maize production technologies in Southern Highlands of Tanzania. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT), The United Republic of Tanzania, and the Southern African Centre for Cooperation in Agricultural Research (SACCAR). p. 38.

Bonabana-Wabbi J. (2002). Assessing Factors Affecting Adoption of Agricultural Technologies: The Case of Integrated Pest Management (IPM) in Kumi District. Msc. Thesis Eastern Uganda.

Bottai, M., Cai, B., and McKeown R. E. (2009). Logistic quantile regression for bounded outcomes. *Statistics in Medicine,* 29 (2), 309-317.

Boughton, D., Mather, D., Barrett, C. B., Benfica, R., Abdula, D., Tschirley, D., and Cunguara, B. (2007). Market Participation by Rural Households in a Low-Income Country: An Asset-Based Approach Applied to Mozambique. *Faith and Economics,* 50, 64–101.

Bruce, A.K.K., Donkoh, S.A., and Ayamga, M. (2014). Improved rice variety adoption and its effects on farmer's output in Ghana. *Journal of Development and Agricultural Economics,* 6(6), 242-248.

Buchinsky, M. (1994). Changes in the U.S. wage structure 1963-1987: Application of quantile Regression. *Econometrica,* 62(2), 405–458.

Buri, M. M., Issaka, R. N., Wakatsuki, T., and Kawano, N. (2012). Improving the Productivity of Lowland Soils for Rice Cultivation in Ghana: The Role of the 'Sawah' System. *Journal of Soil Science and Environmental Management,* 3 (3), 56–62.

Bwalya, R., Mugisha, J., and Hyuha, T. (2013). Transaction costs and smallholder household access to maize markets in Zambia. *Journal of Development and Agricultural Economics,* 5 (9), 328–336.

Cappellari, L., and Jenkins, S.P. (2003). Multivariate probit regression using simulated maximum likelihood. *Stata Journal*, 3(3), 278–297.

Cazzuffi, C., and McKay, A. (2012). Rice market participation and channels of sale in rural Vietnam. In Selected Paper prepared for presentation at the International Association of Agricultural Economists (IAAE) Triennial Conference, Brazil (18-24 August).

CCVRRG. (2015). Catalogue of crop varieties released and registered in Ghana (CCVRRG), Volume No. 1, 2015.

Challa, M. (2013). Determining Factors and Impacts of Modern Agricultural Technology Adoption in West Wollega: the Case of Gulliso District. Master's Thesis, 2013.

Challa, M., and Tilahun, U. (2014). Determining Factors and Impacts of Modern Agricultural Technology Adoption in West Wollega: the Case of Gulliso District. *Journal of Biology, Agriculture and Healthcare,* 20 (4).

Chamberlin, J. (2007). Defining Smallholder Agriculture in Ghana: Who are smallholders, what do they do and how are they linked with markets? Ghana Strategy Support Program. Background Paper No. GSSP 0006.

Chilonda, P., and Otte, J. (2006). Indicators to monitor trends in livestock production at national, regional and international levels. *Livestock Research for Rural Development 18 (8).*

Conley, T.G., and Udry, C. R. (2003). Learning about a New Technology: Pineapple in Ghana. *American Economic Review,* 100(1), 35-69.

Darfour, B. and Rosentrater, K. A. (2016). Agriculture and Food Security in Ghana. A 2016 ASABE Annual International Meeting, Florida July 17-20, 2016. Paper Number: 162460507. https://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=1482&context=abe_eng_conf
Dehejia, H.R., and Wahba, S. (2002). Propensity score matching methods for non-experimental causal studies. *The Review of Economics Statistics,* 84(1), 151-161.

Diagne, A., and Demont, M. (2007). Taking a new look at empirical models of adoption: Average treatment effect estimation of adoption rates and their determinants. *Agricultural Economics,* 37(2-3), 201–210.

Diao, X., and Hazell, P. (2004). Exploring market opportunities for African smallholders. Technical report, International Food Policy Research Institute (IFPRI).

Dida, M. F. (2017). Review papper on determining stocking rate in tropical countries by the use of tropical animal unit month (Taum). *International journal of microbiology and biotechnology,* 2(1), 48-51.

Diiro, G. (2013). Impact of Off-farm Income on Technology Adoption Intensity and Productivity: Evidence from Rural Maize Farmers in Uganda. International Food Policy Research Institute, Working Paper 11.

Dimara, E., and Skuras, D. (2003). Adoption of Agricultural Innovations as a Two Stage Partial Observability Process. *Agricultural Economics,* 28(3), 187-196.

Dixon, J., Tanyeri-Abur, Y., and Wattenbach, H. (2004). "Smallholders, globalisation and policy analysis". Agricultural Management, Marketing and Finance service occasional paper 5, Agricultural support systems division, FAO, Rome, 2004, http://www.fao.org/docrep/007/y5784e/y5784e02.htm#bm02,

Djalalou-Dine A. A. A., Pascucci, S., Linnemann, A.R., Coulibaly, O. N., Hagelaar, G., and Omta, O. S. W. F. (2015). Marketing Channel Selection by Smallholder Farmers. *Journal of Food Products Marketing*, 21(4), 337-357.

Dorfman, J. H. (1996). Modeling multiple adoption decisions in a joint framework. *American Journal of Agricultural Economics*, 78(3), 547–557.

Doss, C. R. (2003). Analysing Technology Adoption: Challenges and Limitations of Micro-Studies**.** *Agricultural Economics*, 34(3), 207 - 219.

Dzudzor, M. I. (2013). Analysis of Rice Production and Opportunities in Ghana. A Thesis Presented to The Faculté d'Ingénierie Biologique, Agronomique et Environnementale at Université catholique de Louvain. August 2013.

Egbetokun, O. A., and Omonona, B. T. (2012): Determinants of Farmers' Participation in Food Market in Ogun State. *Global Journal of Science Frontier Research Agriculture and Veterinary Sciences*, 9(12), 24–30.

Ehui, S., Benin, S., and Paulos, Z. (2009). Policy Options for Improving Market Participation and Sales of Smallholder Livestock Producers: A Case Study of Ethiopia. Draft Prepared for Presentation at the 27th Conference of the International Association of Agricultural Economists (IAAE), 16-22 August 2009, Beijing, China.

Eide, E., and Showalter, M. H. (1998). The effect of school quality on student performance: A quantile regression approach. *Economics Letters*, 58(3), 345-350.

Ellis, F., and Freeman, H. A. (2004). Rural Livelihoods and Poverty Reduction Strategies in Four African Countries. *Journal of Development Studies*, 40(4), 1-30.

Faltermeier L. (2007). Adoption of water conservation and intensification technologies in the lowland rice production system of northern Ghana. Paper presented at the MEIDE Conference, Maastricht, Netherlands.

FAO. (2003). Compendium of Agricultural – Environmental Indicators. Statistics Division, FAO, Rome.

FAO. (2012). Smallholders and Family Farmers. Retrieved from, http://www.fao.org/fileadmin/templates/nr/sustainability_pathways/docs/Factsheet_SMALLHOLDERS.pdf.

FAO. (2013). Comparative table: Eco-functional, sustainable and Ecological intensification, Seventh Framework Programme Food and Agriculture Organisation. Retrieved from, http://agrobiodiversityplatform.org/liberation/wp-content/uploads/2014/05/Comparative-table-intensification.pdf

FAO. (2015). Statistical Pocketbook 2015, World food and Agriculture. Food and Agriculture Organization of the United Nations, Rome, 2015. http://www.fao.org/3/a-i4691e.pdf

Feder G., Just, R. E., and Zilberman D. (1985). Adoption of Agricultural Innovations in Developing Countries: A Survey. *Economic Development and Cultural Change*, 33(2), 255-298.

Francesconi, G. N., and Heerink, N. (2010). Ethiopian agricultural cooperatives in an era of global commodity exchange: Does organisational form matter? *Journal of African Economies*, 20(1), 1–25.

Frölich, M. (2004). Finite-sample properties of propensity-score matching and weighting estimators. *The Review of Economics and Statistics*, 86(1), 77–90.

Frölich, M. (2007). On the inefficiency of propensity score matching. *Advances in Statistical Analysis*, 91(3), 279-290.

Gautam, Y., and Andersen, P. (2016). Rural livelihood diversification and household well-being: Insights from Humla, Nepal. *Journal of Rural Studies,* 44(2), 239-249.

Gebremedhin, B., and Hoekstra, D. (2007). Cereal Marketing and Household Market Participation in Ethiopia: The Case of Teff, Wheat and Rice. Second International Conference, August 20-22, 2007, Accra, Ghana, African Association of Agricultural Economists (AAAE). Conference Proceedings, 2007, 243-252.

Gebreselassie, S., and Ludi, E. (2008). Agricultural Commercialisation in Coffee Growing Areas of Ethiopia, Future Agriculture, University of Sussex, Brighton, UK. http://r4d.dfid.gov.uk/PDF/Outputs/Futureagriculture/coffee_paper.pdf

Ghimire, R., Wen-Chi, H., and Shrestha, R.B. (2015). Factors Affecting Adoption of Improved Rice Varieties among Rural Farm Households in Central Nepal. *Rice Science,* 22(1), 35−43.

Goetz, S. J. (1992). A selectivity model of household food marketing behavior in sub-Saharan Africa. *American Journal of Agricultural Economics,* 74 (2), 444–452.

Goodwin, B., and Mishra, A. (2002). Farming Efficiency and the Determinants of Multiple Job Holding by Farm Operators. *American Journal of Agricultural Economics,* 86 (3), 722–729.

Govereh, J., Jayne, T. S., and Nyoro, J. (1999). Smallholder Commercialisation, Interlinked Markets and Food Crop Productivity: Cross-Country Evidence in Eastern and Southern Africa. The Department of Agricultural Economics and the Department of Economics, Michigan State University (MSU). Retrieved from http://www.aec.msu.edu/fs2/ag_transformation/atw_govereh.

Greene, W. H. (2003). Econometric analysis (5th ed.). New Jersey: Prentice Hall.

Greene, W.H. (2012). Econometric analysis (7th ed.). Prentice Hall, Pearson, NJ.

GRIB. (2012). Ghana Rice Inter-Professional Body (GRIB) Strategic Plan 2013 - 2017, prepared by JMK Consulting Ltd, Accra.

GSS. (2012). 2010 Population and Housing Census: Summary Report of Final Results. Ghana Statistical Service (GSS), Accra, Ghana.

GSS. (2014). Ghana Living Standards Survey Report of the Fifth Round. Ghana Statistical Service (GSS), Accra, Ghana, (GLSS6).

GSS. (2018). Provisional 2017 Annual Gross Domestic Product. Ghana Statistical Service (GSS), Accra, Ghana. April 2018 Edition. http://www.statsghana.gov.gh/docfiles/GDP/GDP2018/2017%20Quarter%204%20and%20annual%202017%20GDP%20publications/Annual_2017_GDP_April%202018%20Edition.pdf

Guiterrez, M. (2003). Macro Economics: Making Gender Matter Concepts, Policies and Institutional Change in Developing Countries. Zed Book.

Guo, S., and M. W. Fraser (2014). Propensity score analysis: Statistical methods and applications. Sage Publications.

Hall, B., and Khan, B. (2002). Adoption of new technology. New Economy Handbook.

Hammond, P. B. (1966). Yatenga: Technology in the Culture of a West African Kingdom. Free Press (January 1, 1966), New York.

Harder, V. S., Stuart, E. A., and Anthony, J. C. (2010). Propensity score techniques and the assessment of measured covariate balance to test causal associations in psychological research. *Psychological Methods*, 15, 234-249.

Hazell, P. (2011). Transformations in agriculture and their implications for rural development. *Electronic Journal of Agricultural and Development Economics*, 4, 47-65.

Hazell, P., and Wood, S. (2008). Drivers of change in global agriculture. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 363, 495-515.

Heckman, J., Ichimura, H., Smith, J., and Todd, P. (1998). Characterizing selection bias using experimental data. *Econometrica*, 66 (5), 1017-1098.

Heckman, J.J. (1979). Sample selection bias as a specification error. *Econometrica*, 47 (1), 153-161.

Holloway, G., Barrett, C. B., and Ehui, S. (2005). The Double-Hurdle Model in the Presence of Fixed Costs. *Journal of International Agricultural Trade and Development*, 1, 17–28.

Hsiao, C. (2003). Analysis of panel data (2nd Ed.). New York: Cambridge University Press.

IFAD-IFPRI. (2011). Agricultural commercialisation in northern Ghana. Innovative Policies on Increasing Access to markets for High-Value Commodities and Climate Chane Mitigation. IFAD-IFPRI Partnership Newsletter.

Imbens, G. W., and Wooldridge, J. M. (2009). Recent Developments in the Econometrics of Program Evaluation. *Journal of Economic Literature, 47(1), 5-86.*

Jaleta, M., Gebremedhin, B., and Hoekstra, D. (2009). Improving Productivity and Market Success of Ethiopian Farmers Project (IPMS). Smallholder commercialisation: processes, determinants and impact. ILRI Discussion Paper 18. Nairobi (Kenya): ILRI.

Jann, B. (2017). Kernel matching with automatic bandwidth selection. 2017 London Stata Users Group meeting, London, September 7–8, 2017. Cass Business School, https://www.stata.com/meeting/uk17/slides/uk17_Jann.pdf

Javed, S. A., Kishwar, S., and Iqbal, M. (2015). From Perceptions to Adaptation to Climate Change: Farm Level Evidence from Pakistan. Pakistan Institute of Development Economics, Islamabad, Pakistan. Climate Change Working Papers No.7

Johannes, C.B., Le, T.K., Zhou, X., Johnston, J.A., and Dworkin, R.H. (2010). The prevalence of chronic pain in United States adults: results of an Internet-based survey. *Journal of pain 11 (11), 1230–1239.*

Johnston, J. (1991). Econometric Methods (3rd ed.). California: McGraw-Hill Book Company.

Kasenge, V. (1998). Socio-economic factors influencing the level of Soil Management Practices on Fragile Land. In Proceedings of the 16th Conference of Soil Science Society of East Africa, 13th-19th, December 1998, Tanga, Tanzania pp.102-112, 1998.

Kassie, M., Marenya, P., Tessema, Y., Jaleta, M., Zeng, D., Erenstein, O., and Rahut, D. (2018). Measuring Farm and Market Level Economic Impacts of Improved Maize Production Technologies in Ethiopia: Evidence from Panel Data. *Journal of Agricultural Economics*, 69(1), 76–95.

Katungi, E., and Akankwasa, K. (2010). Community-Based Organizations and their Effect on the Adoption of Agricultural Technologies in Uganda: a Study of Banana (Musa spp.) Pest Management Technology. *Acta Horticulturae* , 879, 719-726.

Kazianga, H., and Wahhaj, Z. (2013). Gender, social norms, and household production in Burkina. *Economic Development and Cultural Change*, 61(3), 539-576.

Key, N., Sadoulet, E., and de Janvry, A. (2000). Transactions Costs and Agricultural Household Supply Response. *American Journal of Agricultural Economics*, 82(2), 245– 59.

Key, N., Sadoulet, E., and DeJanvry, A. (2000). Transactions Costs and Agricultural Household Supply Response. *American Journal of Agricultural Economics*, 88 (2), 245-259.

Khanna, M. (2001). Sequential adoption of site-specific technologies and its implications for nitrogen productivity: A double selectivity model. *American Journal of Agricultural Economics*, 83(1), 35–51.

King, G., and Nielsen, R. (2016). Why Propensity Scores Should Not Be Used for Matching.Yale University, MacMillan-CSAP Workshop on Quantitative Research Methods. Thursday, March 10, 2016. https://gking.harvard.edu/presentations/why-propensity-scores-should-not-be-used-matching-6

Koenker, R. (2004). Quantile Regression for Longitudinal Data. *Journal of Multivariate Analysis*, 91(1), 74-89.

Koenker, R. (2005). Quantile Regression. Econometric Society Monograph Series, Cambridge: Cambridge University Press, 2005.

Koenker, R., and Bassett, G. (1978). Regression quantiles. *Econometrica*, 46(1), 33-50.

Koenker, R., and Machado, J. (1999). Goodness of fit and related inference processes for quantile regression. *Journal of the American Statistical Association*, 94(1), 1296-1310.

Kohansal, M. R., and Firoozzare, A. (2013). Applying multinomial logit model for determining socio-economic factors affecting major choice of consumers in food purchasing: The case of Mashhad. *Journal of Agricultural Science and Technology*, 15, 1307–1317.

Kohli, I., and Singh, N. (1998). Exports and Growth: Critical minimum effort and diminishing returns. *Journal of Development Economics*, 1 (30), 391-400.

Komarek, A. (2010). The determinants of banana market commercialization in Western Uganda. *African Journal of Agricultural Research*, 5(9), 775-784.

Kostov, P., and Davidova, S. (2012). A Quantile Regression Analysis of the Effect of Farmers' Attitudes and Perceptions on Market Participation. *Journal of Agricultural Economics*, 64(1), 112-132.

Kranjac-Berisavljevic, G. (2000). Some features of Rice Production in Ghana. Paper presented at the National workshop on Rice Production in Ghana. Multi-Agency Partnerships for Technical Change in West African Agriculture through the study of rice production systems in Mali, Nigeria and Ghana. November, 2000.

Langyintuo, A. S., and Dogbe, W. (2005). Characterizing the constraints for the adoption of a Callopogonium mucunoides improved fallow in rice production systems in northern Ghana. *Agriculture, Ecosystems and Environment,* 110(1), 78–90.

Lavison, R. (2013). Factors Influencing the Adoption of Organic Fertilizers in Vegetable Production in Accra. Msc Thesis, Accra Ghana.

Loevinsohn, M., Sumberg, J., and Diagne, A. (2012). Under what circumstances and conditions does adoption of technology result in increased agricultural productivity? Protocol. London: EPPI Centre, Social Science Research Unit, Institute of Education, University of London.

Makhura, M. N., Kirsten, J., and Delgado, C. (2001). Transaction Costs and Smallholder Participation in the Maize Market in the Northern Province of South Africa. In Seventh Eastern and Southern Africa Regional Maize Conference, Pretoria, South Africa. 11–15 February (pp. 463–467).

Manda, P. (2011). Evaluation report on the impact of spray service technology update on small-scale farmer livelihoods in Zambia. CARE, Zambia.

Mango, N., Makate, C., Tamane, L., Mponele, P., and Ndengu, G. (2017). Awareness and adoption of soil and water conservation practices in the Chinyanja Triangle in Southern Africa. *International Soil and Water Conservation Research,* 5(2), 122-129.

Martey, E. (2014). Market Information and Extent of Agricultural Commercialization: Empirical Evidence from Smallholder Farmers in Effutu Municipality of Ghana. *American Journal of Experimental Agriculture,* 4(12), 1680-1696.

Martey, E., Al-hassan, R. M., and Kuwornu, J. K. M. (2012). Commercialization of smallholder agriculture in Ghana; A Tobit regression analysis. *African Journal of Agricultural Research,* 7(14), 2131–2141.

Martey, E., Wiredu, A. N., Etwire, P. M., Fosu, M., Buah, S. S. J., Bidzakin, J., Ahiabor, B. D. K., and Kusi, F. (2014). Fertilizer Adoption and Use Intensity among Smallholder Farmers in Northern Ghana: A Case Study of the AGRA Soil Health Project. *Sustainable Agriculture Research,* 3(1).

Mather, D., Boughton, D., and Jayne T.S. (2011). Smallholder Heterogeneity and Maize Market Participation in Southern and Eastern Africa: Implications for Investment Strategies to Increase Marketed Food Staple Supply: MSU International Development, Working Paper.

Melesse, M. T. (2017). Agricultural Intensification and Market Participation under Learning Externality: Impact Evaluation on Small-scale Agriculture. Maastricht University and UNU-MERIT. February 23, 2017.

MiDA. (2010). Investment Opportunity in Ghana: Maize, Rice, and Soybean. Millennium Development Authority (MiDA), Accra, Ghana.

Mignouna, D. B., Manyong, M., Rusike, J., Mutabazi, S., and Senkondo, M. (2011). Determinants of Adopting Imazapyr-Resistant Maize Technology and its Impact on Household Income in Western Kenya. *AgBioforum*, 14(3), 158-163.

Mignouna, D. B., Abdoulaye, T., Alene, A., Akinola, A. A., Manyond, V. M. (2015). Drivers of market participation decisions among Small-scale farmers in yam areas of Nigeria and Ghana. International Coference of Agricultural Economists. Italy, 2015.

MoFA. (2007). Food and Agriculture Sector Development Policy II (FASDEP II, 2007). Draft, Ministry of Food and Agriculture, Accra.

MoFA. (2009). Agriculture in Ghana. Facts and Figures 2008. Statistics, Research and Information Directorate (SRID), Ministry of Food and Agriculture (MoFA), Accra, Ghana.

MoFA. (2009). National Rice Development Strategy (NRDS), Ministry of Food and Agriculture, Ghana.

MOFA. (2010). Agriculture in Ghana: Facts and Figures, 2009. MOFA/SRID, Accra. Ghana.

MoFA. (2010). Medium Term Agriculture Sector Investment Plan, 2011– 2015. Copyright © Ministry of Food and Agriculture (MOFA), Ghana, 2010. Published in collaboration with Agriculture Sector Stakeholders. ISBN: 978 - 9988 - 1 - 4656 – 6.

MoFA. (2011). Agriculture in Ghana. Facts and figures 2010. Statistics, Research and Information Directorate (SRID), Ministry of Food and Agriculture (MoFA), Accra, Ghana.

MoFA. (2015). Medium Term Agriculture Sector Investment Plan (METASIP) II, 2014 – 2017. Ministry of Food and Agriculture, December 2015. Copyright© Ministry of Food and Agriculture (MOFA), Ghana.

MoFA. (2016). Agricultural Sector Progress Report, 2016. Monitoring and Evaluation Directorate, Ministry of Food and Agriculture (MoFA), Ghana.

MoFA. (2016). Agriculture in Ghana. Facts and Figures 2015. Statistics, Research and Information Directorate (SRID), Ministry of Food and Agriculture (MoFA), Accra, Ghana.

MoFA. (2017). Planting for Food and Jobs Strategic Plan for Implementation (2017 - 2020), Ministry of Food and Agriculture (MoFA), Accra, Ghana. October, 2017. http://mofa.gov.gh/site/wp-content/uploads/2018/03/PFJ%20document%20New%20New.pdf

MoFEP. (2016). Ministry of Finance and Economic Planning the Republic of Ghana, MoFEP, http://www.mofep.gov.gh/?q=news/040811_2

Morris, M., and Doss, C. (1999). How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana: Paper Presented at the Annual Meeting, American Agricultural Economics Association (AAEA), Nashville, Tennessee, August 8-11.

Mugisa-Mutetikka, M., Opio, A. F., Ugen, M. A., Tukamuhabwa, P., Kayiwa, B. S., Niringiye, C., and Kikoba, E. (2000). Logistic Regression Analysis of Adoption of New Bean Varieties in Uganda.

Mulisa, F. D. (2017). Review Paper on Determining Stocking Rate in Tropical countries by the use of Tropical Animal Unit Month (TAUM). *International Journal of Microbiology and Biotechnology*, 2(1), 48-51. http://article.sciencepublishinggroup.com/pdf/10.11648.j.ijmb.20170201.19.pdf

Muricho, G. S. (2015). Determinants of agricultural commercialization and its impacts on welfare among smallholder farmers in Kenya. PhD Theses of the University of Nairobi, Nairobi.

Musah, A.B. (2013). Market participation of smallholder maize farmers in the Upper West region of Ghana. *African journal of agricultural research,* 9(31), 2427-2435.

Muzari, W., Gatsi, W., and Muvhunzi, S. (2012). The Impacts of Technology Adoption on Smallholder Agricultural Productivity in Sub-Saharan Africa: A Review, *Journal of Sustainable Development*, 5 (8).

Mwangi, M., and Kariuki, S. (2015). Factors Determining Adoption of New Agricultural Technology by Smallholder Farmers in Developing Countries. *Journal of Economics and Sustainable Development,* 6(5), 2015.

Namara, E., Weligamage, P., and Barker, R. (2003). Prospects for adopting system of rice intensification in Sri Lanka: A socioeconomic assessment. Research Report 75.Colombo, Sri Lanka: International Water Management Institute.

Ndiritu, S. W., Kassie, M., and Shiferaw, B. (2014). Are there systematic gender differences in the adoption of sustainable agricultural intensification practices? Evidence from Kenya. *Food Policy*, 49(1), 117-127.

NDPC. (2014). Ghana Shared Growth and Development Agenda (GSGDA) II, 2014-2017. National Development Planning Commission (NDPC).

Newman, C., Henchion, M., and Matthews, A. (2003). A double-hurdle model of irish household expenditure on prepared meals. *Applied Economics*, 35 (9), 1053–1061.

Nguezet, P. M. D., Diagne, A., Okoruwa, V. O., and Ojehomon, V. (2011). Impact of improved rice technology (NERICA varieties) on income and poverty among rice farming households in Nigeria: a local average treatment effect (LATE) approach. Quarterly *Journal of International Agriculture.* 50 (3), 267–292.

Norman, J.C., and Otoo, E. (2002). Sustainable rice production for food security. Proceedings of the 20th Session of the International Rice Commission Bangkok, Thailand, 23-26 July 2002. International Rice Commission.

Norton, D. R. (2004). Agricultural Development Policy: Concepts and expectations. John Wiley & Sons,Chichester, UK. 528 p.

Nwanze K. F., Mohapatra, S., Kormawa, P., Shellemiah, K., and Bruce-Oliver, S. (2006). Rice development in Sub-Saharan Africa. *Journal of Science, Food and Agriculture*, 86(5), 675-677.

Olwande, J., and Mathenge, M. (2012). Market Participation among Poor Rural Households in Kenya. In Paper Presented at the International Association of Agricultural Economists Triennial Conference, Brazil. (18-24 August).

Omiti, J. M., Otieno, D. J., Nyanamba, T. O., and McCullough, E. (2009). Factors influencing the intensity of market participation by smallholder farmers: A case study of rural and peri-urban areas of Kenya. *African Journal of Agricultural and Resource Economics*, 3(1), 57–82.

Onoja, O., Usoroh, B. B., Adieme, D. T., and Deedam N. J. (2012). Determinants of Market Participation in Nigerian Small Scale Fishery Sector: Evidence from Niger Delta Region. *Journal of Sustainable Development*, 9 (1), 69–84.

Opondo, F.A., Dannenberg, P., and Willkomm, M. (2017). Characterization of the levels of cassava commercialization among smallholder farmers in Kenya: A multinomial regression approach. African Journal of Agricultural Research, 12(41), 3024-3036. https://doi.org/10.5897/AJAR2017.12634

Ouma, J., Murithi, F., Mwangi, W., Verkuijl, H., Gethi M., and De Groote, H. (2002). Adoption of Maize Seed and Fertilizer Technologies in Embu District, Kenya. CIMMYT (International Maize and Wheat Improvement Center), Mexico, D.F.

Pender, J., and Alemu, D. (2007). Determinants of Smallholder Commercialization of Food Crops: Theory and Evidence from Ethiopia. Discussion Paper No. 75, IFPRI, Washington D.C.

Pingali, P. (2007). Agricultural growth and economic development: a view through the globalization lens. *Agricultural Economics*, 37, 1-12.

Pingali, P. L. (1997). From subsistence to commercial production systems: The transformation of Asian agriculture. *American Journal of Agricultural Economics*, 628–634.

Pingali, P. L., and Rosegrant, M. W. (1995). Agricultural commercialization and diversification: processes and policies. *Food policy*, 20 (3), 171–185.

Polson, R. A., and Spencer, D. S. C. (1992). The Technology Adoption Process in Subsistence Agriculture: The Case of Cassava in Southwestern Nigeria. *Agricultural Systems,* 36(1), 65-78.

Poole, N. (2017). Smallholder Agriculture and Market Participation. Rugby, UK: Practical Action Publishing, Published by Food and Agriculture Organization of the United Nations and Practical Action Publishing 2017. http://dx.doi.org/10.3362/9781780449401

Poulton, C., and Leavy, J. (2007). Commercialization's in Agriculture. *Ethiopian Journal of Economics*, 16(1).

Powell, D. (2011). Unconditional Quantile Regression for Exogenous or Endogenous Treatment Variables. WR-824, RAND Labor and Population working paper series.

Pradhan, K., Dewina, R., and Minsten, B. (2010). Agricultural Commercialization and Diversification in Bhutan. International Food Policy Research Institute (IFPRI), Washington, DC, USA.

Quaye, W. (2007). Food Sovereignty and combating poverty and hunger in Ghana. Tailoring Biotechnology, 3(2), 101-108.

Ragasa, C., and Chapoto, A. (2017). Limits to Green Revolution in Rice in Africa: The Case of Ghana. *Land use policy,* 66(1), 304-321.

Ragasa, C., Dankyi, A., Acheampong, P., Wiredu, A. N., Chapoto, A., Asamoah, M., and Tripp, R. (2013). Patterns of Adoption of Improved Maize Technologies in Ghana. GSSP Working Paper 35 Washington, D.C.: International Food Policy Research Institute (IFPRI) http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/127765

Ragasa, C., Takeshima, H., Chapoto, A., and Kolavalli, K. (2014). Substituting for Rice Imports in Ghana. Ghana Strategy Support Program Policy Note 6. Washington, D.C.: International Food Policy Research Institute (IFPRI). http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/128264

Reardon, T., Stamoulis, K., and Pingali, P. (2007). Rural Nonfarm Employment in Developing Countries in an era of Globalization. *Agricultural Economics,* 37(1), 173–183.

Reardon, T., Timmer, P. C., Barret, C. B., and Berdegue, J. (2003). The Rise of Supermarkets in Africa, Asia and Latin America. *American Journal of Agricultural Economics,* 85(5), 1140-1146.

Reyes, B., Donovan, C., Bernsten, R., and Maredia, M. (2012). Market participation and sale of potatoes by smallholder farmers in the central highlands of Angola: A Double Hurdle Approach. In Selected Paper prepared for presentation at the International Association of Agricultural Economists (IAAE) Triennial Conference, Brazil. (18-24 August). https://pdfs.semanticscholar.org/6d43/39f27a8b7974a8fe736b6e49d08dc2a669d7.pdf

Rogers, E. M. (2003). Diffusion of innovations (5th Ed). New York: Free Press

Rogers, E. M, (1962). Diffusions of innovations. New York: Free Press.

Rogers, E. M., and Shoemaker, F.F. (1971). Communication of Innovation: A Cross-Cultural Approach. 2nd Ed., New York: Free Press.

Rosenbaum, P. R. (2002). Observational Studies (2nd edn). Springer Series in Statistics, Springer-Verlag, New York, 2002.

Rosenbaum, P. R., and Rubin, D.B. (1983). The central role of the propensity score in observational studies for casual effects. *Biometrika,* 70 (1), 41–55.

Samiee, A., Rezvanfar, A., and Faham, E. (2009). Factors affecting adoption of integrated pest management by wheat growers in Varamin County, Iran. *African Journal of Agricultural Research,* 4(5), 491-497.

Sebatta, C., Mugisha, J., Katungi, E., Kashaaru, A., and Kyomugisha, H. (2014). Smallholder Farmers' Decision and Level of Participation in the Potato Market in Uganda. *Modern Economy,* 5(8), 895-906.

Seidu, A., Sarpong, D. B., and Al-Hassan, R. (2004). Allocative Efficiency, Employment and Rice Production Risk: An analysis of small holder paddy farms in the Upper East Region of Ghana. *Ghana Journal of Development Studies,* 1(2).

Sigei, G., Bett, H., and Kibet, L. (2014). Determinants of Market Participation among Small-scale Pineapple Farmers in Kericho County, Kenya. MPRA Paper No. 56149. http://mpra.ub.uni-muenchen.de/56149/

Simtowe, F., and Zeller, M. (2006). The Impact of Access to Credit on the Adoption of hybrid maize in Malawi:An Empirical test of an Agricultural Household Model under credit market failure. MPRA Paper No. 45. https://mpra.ub.uni-muenchen.de/45/1/MPRA_paper_45.pdf

Siziba, S., Kefasi, N., Diagne, A., Fatunbi, A. O., and Adekunle, A. A. (2011). Determinants of cereal market participation by sub-Saharan Africa smallholder farmer. *Journal of Agriculture and Environmental studies,* 2(1), 180–193.

Smith, J., and Todd, P. (2005). Does matching overcome LaLonde's critique of non-experimental Estimators? *Journal of Econometrics,* 125(1-2), 305-353.

Stock, J. H., and Watson, M. M. (2012). Introduction to Econometrics (3rd ed.). Princeton: Pearson Education Limited.

Strauss, D., Bednar, L., and Mees, R. (1989). Do one percent of forest fires cause ninety-nine percent of the damage? *Forest Science,* 35, 319–328.

Tarekegn, K., Haji, J., and Tegegne, B. (2017). Determinants of honey producer market outlet choice in Chena District, southern Ethiopia: a multivariate probit regression analysis. *Agricultural and Food Economics,* 5 (20).

Theis, S., Lefore, L., Meinzen-Dick, R. S., and Bryan, E. (2018). What happens after technology adoption? Gendered aspects of small-scale irrigation technologies in Ethiopia, Ghana, and Tanzania. IFPRI Discussion Paper 1672. Washington, D.C.: International Food Policy Research Institute (IFPRI). http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/131375

TLU. (2011). Tropical Livestock Units (TLU) Archived 2011-02-23 at the Wayback Machine. Paper about livestock units from Livestock and Environment Toolbox. FAO (auf fao.org).

Tobin, J. (1958). Estimation of Relationships for Limited Dependent Variables. *Econometrica*, *26*(1), 24–36.

Todaro, M. P., and Smith, S. C. (2011). Economic Development. Boston: Pearson Addison Wesley.

Todaro, M. P., and Smith, S. C. (2012). Economic development, (11th ed). Pearson Addison-Wesley publications: USA: 359-404.

Tura, E. G., and Hamo, T. K. (2018). Determinants of Tomato Smallholder Farmers Market Outlet Choices in West Shewa, Ethiopia. *Journal of Agricultural Economics and Rural Development*, 4(2), 454-460.

Uaiene, R., Arndt, C., and Masters, W. (2009). Determinants of Agricultural Technology Adoption in Mozambique. Discussion papers No. 67E. National Directorate of Studies and Policy Analysis, Ministry of Planning and Development, Republic of Mozambique.

Udvardy, M., and Cattell, M. (1992). Gender, aging and power in sub-Saharan Africa: Challenges and puzzles. *Journal of Cross-Cultural Gerontology*, 7(4), 275–288.

Uematsu, H., and Mishra, A. (2010). Can Education Be a Barrier to Technology Adoption? Selected Paper prepared for presentation at the Agricultural & Applied Economics Association 2010 (AAEA), CAES and WAEA Joint Annual Meeting, Denver, Colorado, 25-27, 2010. https://ageconsearch.umn.edu/bitstream/61630/2/11158%20AAEA%20Education%20Paper.pdf

USAID. (2009). Global Food Security Response West Africa Rice Value Chain Analysis, USAID, http://pdf.usaid.gov/pdf_docs/pnaea870.pdf

USAID. (2012). The Market for Maize, rice, Soy, and Warehousing in northern Ghana. United States Agency for International Development (USAID) - Enabling Agricultural Trade (EAT) project. Fintrac International publishing.

USDA. (2015). Rice Consumption Statistics. United States Department of Agriculture (USDA).

Van de Walle, D. (2013). Lasting welfare effects of widowhood in Mali. *World Development*, 51(1), 1–19.

Vance, C., and Geoghegan, J. (2004). Modeling the determinants of semi-subsistent and commercial land uses in an agricultural frontier of southern Mexico: a switching regression approach. *International Regional Science Review*, 27 (3), 326–347.

Verbeek, M. (2010). A Guide to Modern Econometrics. Rotterdam: John & Sons, Limited.

Von Braun, J., and Díaz-Bonilla, E. (2008). Globalization of Agriculture and Food: Causes, Consequences and Policy implications. Globalization of food and agriculture and the poor. New Delhi: IFPRI and Oxford University Press.

Waller, B., Hoy, W., Henderson, L., Stinner, B., and Welty, C. (1998). Matching innovation with potential users: A case study of potato IPM practices. *Agriculture, Ecosystems and Environment*, 70 (1), 203-215.

Wan, W. and Hu, W. (2012). At-home Seafood Consumption in Kentucky: A Double-Hurdle Model Approach. Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Birmingham, AL. (4-7 February).

Winship, C., and Mare, R. D. (1992). Models for Sample Selection Bias. *Annual Review of Sociology*, 18, 327-350.

Wiredu. A. N., Gyasi, K. O., Marfo, K. A., Asuming-Brempong, S., Haleegoah, J., Asuming-Boakye, A., and Nsiah, B. F. (2010). Impact of improved varieties on the yield of rice producing households in Ghana. Second Africa Rice Congress, Bamako, Mali, 22–26 March 2010: Innovation and Partnerships to Realize Africa's Rice Potential.

Wiredu, A., Zeller, M. and Diagne, A. (2015). What determines adoption of fertilizers among rice-producing households in northern Ghana? *Quarterly, Journal of International Agriculture*, 54(3), 261-281.

Wooldridge, J. M. (2006). Introductory Econometrics: A Modern Approach. (3rd ed.). South-Western College Publishing.

Wooldridge, J.M. (2005). Instrumental estimation of the average treatment effect in the correlated random coefficient model. *Advances in Econometrics, 21, 93-116.*

Wooldridge, J.M. (2010). Econometric analysis of cross section and panel data. MIT press.

World Weather and Climate Information. (2018). Climate: Average Monthly Weather in Tamale, Ghana. https://weather-and-climate.com/average-monthly-rainfall-temperature-sunshine,tamale,ghana

Yaron, D., Dinar, A., and Voet, H. (1992). Innovations on Family farms: The Nazareth Region in Israel. *American Journal of Agricultural Economics*, 74(2), 361-370.

Yu, B., Nin-Pratt, A., Funes, J., and Gemessa, S. A. (2011). Cereal production and technology adoption in Ethiopia. Ethiopia Strategy Support Program II (ESSP II), ESSP II Working Paper 31.

Yu, K., and Moyeed, R. A. (2001). Bayesian quantile regression. *Statistics and Probability Letters*, 54 (4), 437-447.

Zakaria, A., Ansah, I. G. K., Abdulai, S., and Donkoh, S. A. (2016). The Determinants and Effects of JICA Rice Technology Adoption in the Sagnarigu District of the Northern Region, Ghana. *UDS International Journal of Development [UDSIJD]*, 3(1).

Zamasiya B., Mango N., Nyikahadzoi and Siziba S. (2014). Determinants of Soybean participation by smallholder farmers in Zimbabwe. *Journal of Development and Agricultural Economics*, 6(2), 49-58.

Zhou, Z., Robards, K., Helliwell, S., and Blanchard, C. (2002). Composition and functional properties of rice. *International Journal of Food Science and Technology*, 37(8), 849-868.

APPENDICES

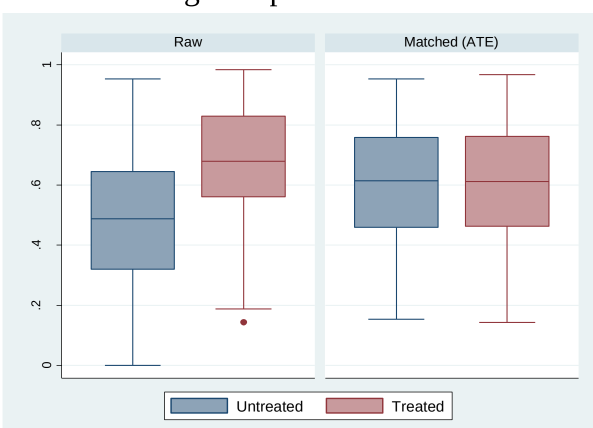
Appendix A

Rosenbaum sensitivity analysis

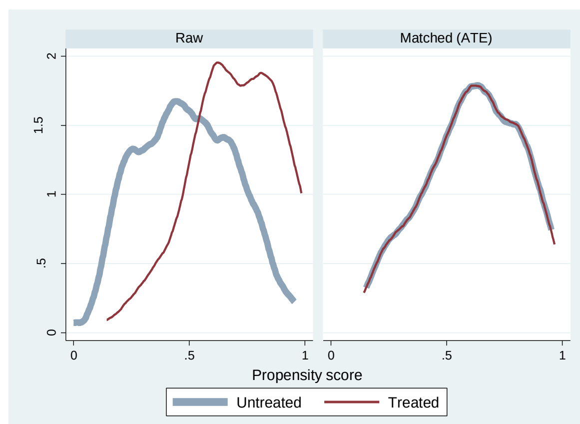
Critical Value of Hidden Bias (г)	Kernel Matching		Nearest Neighbour	
	Sig+	Sig-	Sig+	Sig-
1.00	0.0000000012	0.0000000012	0.00000000083	0.00000000083
1.10	0.000000052	0.000000000016	0.000000038	0.000000000011
1.20	0.0000011	0.00000000000021	0.00000081	0.00000000000014
1.30	0.000013	0.0000000000000024	0.0000098	0.0000000000000016
1.40	0.000096	0	0.000076	0
1.50	0.000511	0	0.000415	0
1.60	0.002039	0	0.001691	0
1.70	0.006431	0	0.00544	0
1.80	0.016706	0	0.014387	0
1.90	0.036908	0	0.032323	0
2.00	0.071184	0	0.063322	0

Post Estimation for balancing

Balancing Box plot



Density Balancing plot



Summary results of joint probabilities, linear predictions and the marginal probabilities from STATA output

Variable	Obs	Mean	Std. Dev.	Min	Max
pall1s	429	.034183	.0402849	1.85e-18	.2882202
pall0s	429	.2028484	.1204397	2.50e-07	.6395016
pmargm1	429	.1657814	.1660736	3.41e-18	.769361
pmargm2	429	.4213276	.2462924	.0081955	.9999995
pmargm3	429	.4681836	.1733004	.1106557	.9994935
pmargm4	429	.3808503	.2098565	1.74e-11	.9076952
pmargm5	429	.4405266	.1385139	.024735	.7888746
stdpm1	429	.3364125	.1595677	.1673479	2.511346
stdpm2	429	.282842	.1319929	.127721	2.053912
stdpm3	429	.2649455	.1243357	.1249563	1.913177
stdpm4	429	.3167651	.2386915	.1280064	2.376082
stdpm5	429	.2538632	.0921345	.1156612	.8729979

pall1s "Joint probability of success"
pall0s "Joint probability of failure"
stdpm "Linear probability" (probability of each of the technologies)
pmargm “Marginal success probability for each equation"

Linear Predictions from MVP

Rice Production Technologies	Linear Predictions
Bunding	33.64 %
Dibbling or Drilling	31.68 %
Herbicides	28.28 %
Improved variety	26.49 %
Chemical fertilizer	25.39 %

Joint Probabilities

Probability of success 3.42 %

Probability of failure 20.28 %

Appendix B

Determinants of adopting improved rice varieties (logistic regression)

Variable	**Coefficient**	**Std. Error**	**P>|z|**
Age of household head	0.0102	0.0085	0.218
Household head decide type of seed to plant	0.7958	0.2400	0.001
Years of farming experience (rice)	-0.0096	0.0118	0.415
Proportion of active members educated	0.9965	0.4814	0.038
Number of salaried males	0.5373	0.2771	0.053
Number of training attended	0.3679	0.2148	0.087
Average plot size(acres)	-0.0170	0.0563	0.763
Planting method	1.1871	0.2646	0.000
Number of livestock	-0.0010	0.0029	0.714
Land ownership	0.5037	0.2575	0.050
Total family labor	0.0060	0.0035	0.086
Source of seed			
Open market	0.3885	0.3698	0.293
Extension agent	0.7683	0.4643	0.098
Agro input shop	0.4670	0.2664	0.080
Quantity of fertilizer per acre			
First application	-0.0004	0.0029	0.881
Second application	0.0043	0.0060	0.474
Number of observation	429		
Wald chi2(16)	63.00		
Prob > chi2	0.0000		
Pseudo R2	0.1453		
Log pseudo-likelihood	-246.56		