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COMMERCIALIZING INNOVATIONS FROM AGRICULTURAL RESEARCH IN NORTHERN GHANA AND FARMERS' WILLINGNESS TO PAY

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DECLARATION

Student

I hereby declare that the thesis is the result of my own original work and that no part of it has been presented for another degree in this University or elsewhere.

Candidate's Signature .....Date.....

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Supervisors

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

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ABSTRACT

The study used contingent valuation to solicit monetary values from researchers and farmers on how much they were willing to sell and buy the following innovations from research respectively: improved seed, soil fertility management techniques, crop protection techniques, safe-use of agro-chemicals as well as farm management and record keeping. Also, a probit model was employed to identify the determinants of researchers' willingness to sell innovations from research. Furthermore a multivariate (MV) probit model was estimated to explain key determinants of farmers' willingness to pay for such innovations (technologies). Multi-stage sampling methods were used to obtain 360 farmers and 51 research scientists for the study. Though majority of farmers were willing to pay for agricultural innovations, the amounts they were prepared to pay were far less than what the researchers wanted them to pay. The probability of a researcher accepting payment for innovations from research was high for the following categories of researchers: younger researchers; researchers who were members of professional bodies; and researchers with a high number of publications. The following categories of farmers also had a higher probability of paying for research output: younger farmers; farmers with high level of formal education; native farmers; farmers who had contact with extension staff; and farmers with high income from their previous farming and non-farming activities. The average WTA and WTP were GH₵50.00 and GH₵6.00 respectively. Considering the wide disparity between researchers' WTA payment for innovations and farmers' WTP, commercialization of research is possible but cannot be run on full cost-recovery. Government should therefore set up a statutory fund dedicated to agricultural research as a way of subsidizing agricultural innovations.

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DEDICATION

I dedicate this work to all those working to make this world a better place to live in.

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LIST OF ACRONYMS

1DC	Single-bounded dichotomous Choice
2DC	Double-bounded dichotomous Choice
A.E.A.	Agricultural Extension Agent
ADVANCE	Agricultural Development and Value Chain Enhancement
AgGDP	Agricultural Gross Domestic Product
AGRA	Alliance for Green Revolution in Africa
ASTI	Agricultural Science and Technology Indicators
AU	Africa Union
AVCMP	Agricultural Value Chain Mentorship Project
BG	Bidding Game
CAADP	Comprehensive Africa Agricultural Development
CDF	Cumulative Distribution Function
CRIG	Cocoa Research Institute of Ghana
CSIR	Council for Scientific and Industrial Research
CV	Contingent Valuation
DANIDA	Danish International Development Agency
ECA	Economic Commission for Africa
FAO	Food and Agricultural Organization
FASDEP	Food and Agriculture Sector Development Policy
FBO	Farmer Based Organization
GAABIC	Ghana Agricultural Associations Business and Information Centre
GDP	Gross Domestic Product
GH₵	Ghana Cedis
GoG	Government of Ghana

GPRS	Ghana Poverty Reduction Strategy
GTZ	German Technical Cooperation Agency
HUGO	International Organization of the Human Genome
IP	Intellectual Property
JICA	Japan International Cooperation Agency
MDGs	Millennium Development Goals
MIDA	Millennium Development Authority
MoFA	Ministry of Food and Agriculture
MTDPF	Medium Term Development Policy Framework
MV	Multivariate
NASA	National Aeronautics and Space Administration
NDPC	National Development Planning Commission
NEPAD	New Partnership for Africa Development
ODI	Overseas Development Institute
OE	Open Ended
OECD	Organization for Economic Cooperation and Development
OLS	Ordinary Least Square
OPRI	Oil Palm Research Institute
OSTP	Office of Science and Technology Policy
PBB	Pilot programme Based Budget
SARI	Savannah Agricultural Research Institute
SME	Small and Medium scale Enterprises
SRID	Statistics, Research and Information Directorate
STEPRI	Science and Technology Policy Research Institute
UDS	University for Development Studies
UNESCO	United Nations Educational, Scientific and Cultural Organization
USAID	United States Agency for International Development

WASA	West Africa Seed Alliance
WASNET	West Africa Seed Network
WIPO	World Intellectual Property Organization
WTA	Willingness to Accept
WTP	Willingness to Pay

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Agriculture is the major source of employment, income, and foreign exchange in most sub-Saharan African countries and, therefore could serve as the pivot for economic growth. The potential for growth lies in improved agricultural productivity and efficiency in the food production process. The improvement depends on advances in technology, which also depends on the institutional frameworks and capacity of personnel for developing the appropriate technologies and the mechanisms for their transfer and commercialization.

In sub-Saharan Africa, the development of sustainable and viable agricultural systems is expected to occur under difficult conditions such as an environment made fragile from degradation; increasing food insecurity emanating from rapid population growth and climate change and competitive economic systems that compel agribusinesses in developing countries to compete with counterparts from other parts of the world, in the name of trade liberalization (Acquah and Gelaw, 1997).

Ghana, just like many countries in sub-Saharan Africa, also recognizes agriculture as the pivot not only for economic growth but a strategic tool for poverty alleviation. The Ghana Poverty Reduction Strategy (GPRS II) Programme recognized that no significant progress can be made in raising the average real incomes of Ghanaians as a whole without significant improvements in the productivity of the agricultural sector and agro-

based/processing industry. Agriculture is therefore expected to lead the growth and structural transformation of Ghana`s economy and maximize the benefits of accelerated growth (NDPC, 2005).

The broad strategic direction for Ghana`s Medium Term Development Policy Framework (MTDPF) 2010-2013 focuses on accelerated agricultural modernization and agro-based industrial development and reducing poverty and income inequalities. A number of strategies have been outlined including improving agricultural extension services and the use of improved seeds (NDPC, 2009).

It is therefore important to note that there have been deliberate and concerted efforts in Ghana`s national development planning, to put agriculture in its rightful place in Ghana`s socio-economic development agenda. This notwithstanding, there are still challenges, especially, low agricultural productivity and low access to innovations from research by farmers.

The underlying causes of low productivity in Ghana`s agriculture are poor soil conditions, low and poor distribution of rainfall, diseases and pest, limited access to planting materials, improved seed varieties and livestock breeds. There are limited appropriate technologies for processing, transporting, handling and storage of crop produce, fish and livestock products. Also, limited knowledge in post-harvest management, particularly of perishable produce have resulted in high post-harvest losses of about 20%-50% for fruits, vegetables, roots and tubers, and about 20%-30% for cereals and legumes. The low application of technologies to alleviate these problems is also attributed to supply driven approach to technology generation and dissemination

(top-down planning) that does not favour adoption (MoFA, 2007). Recent national policy strategies have now been tailored towards increasing productivity in the agricultural sector. For instance, the Food and Agriculture Sector Development Policy (FASDEP II), seeks to improve food security and the country's preparedness to handle emergency situations, sustainable management of land and environment as well as science and technology application in food and agricultural development leading to growth in incomes.

Cutting-edge strategies have been proposed to achieving the objective of science and technology application in food and agriculture development. These include improving access and use of technologies by improving the relevance of technologies to users, promoting demand driven research and ensuring sustained funding of research by partnering with the private sector (including farmer groups) and NGOs to identify and adopt innovation approaches to agricultural research funding and commercialization (MoFA, 2007).

Accordingly, agricultural research and extension services have been restructured to be provided either by the private sector or through improved public entities. The sustainability of the latter depends on resource availability; whereas provision by the private sector is very much a function of farmers` willingness to pay (Ulimwengu and Sanyal, 2011).

Commercialization of agricultural technologies encompasses widespread distribution, adoption, and acceptance of a given technology by key actors in the input, production and / or post-harvest sub-sectors of the food and agricultural systems, as well as sustainability

and the contribution to social values. Commercialization should not only be restricted to profit making operations. The sustainability of a product and its contribution to social values in producing self-sufficiency should be taken into consideration when defining commercialization (Acquah and Gelaw, 1997)

Agricultural research has played a major role in the socio-economic development of Ghana, over the years. Ghana has made progress in the agricultural sector by maintaining an average agricultural GDP growth rate of about five percent (5%) per annum during the past twenty five years. Staple crop production has been increasing faster than population growth, making Ghana largely self-sufficient in terms of staples. While productivity was on the rise, poverty has been declining. Similarly, under-nourishment, child malnutrition, and the proportion of underweight infants have drastically fallen. Implementation and continuous maintenance of important agricultural reforms, a favourable environment for private sector investment and increased expenditure in agricultural research are the major drivers of these progresses (Chauvin *et al*, 2012).

Following a decade of minimal growth, spending on agricultural research and development (R&D) in Ghana increased dramatically after 2002. Expenditures more than doubled from 2000 to 2008. The amount spent, as a percentage of Ghana`s agricultural GDP, was one of the highest in West Africa. The spike in spending, however, was largely due to an increase in salary costs. In 2008, salaries accounted for 83 percent of the agricultural research budget of Ghana`s Council for Scientific and Industrial Research (CSIR), the leading government research organization, which encompasses 13 research

agencies (Flaherty *et al.* 2010). Government and donor contributions remain the primary sources of funding for agricultural research in Ghana (MoFA, 2010).

Therefore, commercializing innovations could be a sustainable way to funding core research and development programmes. This is because innovations emanating from research are the vehicles for promoting agricultural productivity, increasing national economic growth and improving the lives of poor Ghanaian farm families.

1.2 Problem Statement

Agricultural research and technology development in sub-Saharan Africa have been supply- driven without active participation of end-users (farmers, input dealers, and processing firms) and transfer agents (extension officers). This has led to numerous cases of technologies developed, but not transferred or adopted. Too often, supply-driven technologies are not appropriate for the resource-poor end-users. Therefore, what is required is a more demand- driven process that would ensure appropriate technology development, transfer and commercialization (Acquah and Gelaw, 1997).

The funding of Ghana`s agricultural research is very much dependent on donor support. Non-profit organizations and profit-oriented companies alike play a limited role in Ghana`s agricultural research efforts. Although government policy has since a decade ago required CSIR to generate 30 percent of their budget from private sources, only the Oil Palm Research Institute (OPRI) has come close to reaching this target (Flaherty *et al.* 2010). This follows the restructuring of CSIR in 1996 by the Government of Ghana to

make it more responsive to private sector needs and to promote demand driven research through research commercialization. A research commercialization policy was incorporated into the activities of CSIR by an act of Parliament (Act 521 of 1996). This existing Act seeks to promote research commercialization and to ensure that research institutions also generate funds internally to fund their research activities (Appiah et al. 2012).

In recent years, policy makers have advocated the need for research institutions to wean themselves completely off governmental support in terms of budgetary allocations, and be self-sustaining. It is against the backdrop of the increasing cost of agricultural research that commercialization is advocated.

Many have advocated for commercialization of innovations from research and the use of service fees as a viable alternative to a sustainable source of funding of agricultural research in Ghana. But what many people in Ghana have not thought of is the available market space for research commercialization. According to Ulimwengu and Sanyal (2011), successful implementation of such schemes requires understanding of determinants of farmers` willingness to pay.

In recent times, Ghana has made frantic efforts in operationalizing commercialization of some research innovations, especially improved seed commercialization. Notable among them is the enactment of a new law called the Plants and Fertilizer Act 2010. Also, putting in place a Seed Policy and a Plant Breeders Bill is underway. These policy regulations and laws are necessary but not sufficient condition for improving Ghana's agricultural productivity. Supply of good seed is not an end in itself. It is only part of a

number of factors of crop management that contribute to farm productivity. While it is important to examine the seed supply side as the various laws and regulations seek to do, the demand side which is most critical is often overlooked (Tripp and Mensah-Bonsu, 2013). Also, what is often over looked is the demand for the other components of crop management necessary for farm productivity: soil fertility management, field crop protection and post-harvest techniques.

Presently, there is limited empirical research on the level of commercialization of innovations from agricultural research and the possible determinants of farmers` willingness to pay for the innovations. It is also not clear how much researchers will be willing to sell their innovations upon commercialization and how much farmers too will be willing to buy such innovations from researchers. Information on these is crucial in making an informed opinion on whether commercializing innovations from research is a viable and sustainable alternative to public funding of agricultural research in Ghana or not.

Despite minimal budgetary allocation from government towards core research, research institutions continue to respond to the need of finding appropriate technologies to increase the standard of living of farming households in Northern Ghana. Two of such institutions are CSIR-Savanna Agricultural Research Institute (SARI) and the University for Development Studies (U.D.S.). CSIR-SARI, by its mandate, conducts agricultural research, particularly as it relates to food and fibre crop farming in Northern Ghana for the purpose of introducing improved technologies to enhance agricultural productivity. The University for Development Studies (U.D.S.) also conducts research with the aim of

promoting agricultural productivity and socio-economic transformation of communities in northern Ghana. Sometimes researchers from these two institutions implement collaborative research projects.

Considering the fact that most of the research projects being implemented by researchers in Northern Ghana are donor funded, hence not sustainable especially when Ghana is now considered a lower middle income economy and the volatility normally associated with donor funded projects. There is also the urgent need for Northern Ghana to move out of food insecurity.

Despite the legal framework being created for research commercialization in Ghana, many people have asked whether farmers would be willing to pay for research findings.

From the above statements, the following research questions become important:

1. How much are researchers willing to sell agricultural research innovations (improved seed, soil fertility management techniques, crop protection, postharvest techniques as well as farm management and record keeping?
2. Will farmers in Northern Ghana be willing to pay for agricultural research innovations? If they will, how much will they be willing to pay?
3. What factors influence researchers' willingness to sell agricultural research innovations?
4. What are the determinants of farmers' willingness to pay for agricultural research innovations?

These questions have remained unanswered, hence this study. This research seeks to provide a unique contribution in terms of appreciating the underlying factors that may affect commercializing innovations (research findings) in northern Ghana by researchers in the Savanna Agricultural Research Institute (SARI) of the Council for Scientific and Industrial Research (CSIR) and also the University for Development Studies (U.D.S.).

Based on the empirical findings of this research, we wish to derive recommendations for policy measures that shall inform government and other stakeholders on whether farmers would be willing to pay for innovations from research and whether also, commercializing research results would be a viable and sustainable alternative to funding agricultural research in Northern Ghana. There exist for now, not such a study, to the best of our knowledge.

1.3 Objectives of the Study

The main objective of this study is to undertake an ex-ante study on commercialization of innovations from agricultural research and farmers' willingness to pay for these innovations.

The specific objectives included the following:

1. To determine how much researchers would be willing to sell innovative technologies to farmers in the following areas: improved seed varieties, soil fertility management, crop protection, records keeping, post-harvest techniques and safe use of chemicals

2. To determine how much farmers would be willing to pay for these innovative technologies from researchers.
3. To investigate possible factors that can influence the sale of research output in northern Ghana.
4. To examine the potential factors that may affect farmers' willingness to pay for improved technologies.

1.4 Justification

Productivity gains in agriculture are often more effective than those in the other sectors of the economy in terms of poverty reduction (World Bank, 2007). This is because agriculture is the major employer of poor people. An increase in agricultural productivity directly translates to an increase in farm household incomes. Besides, increased food production can reduce the real price of food which may impact positively on the growth of other sectors of the economy (ODI, 2011). Reduced food prices benefit farmers since some of them are generally net-food-buyers. The government of Ghana also considers agricultural development as a key strategy for economic diversification. Agriculture does not only provide food security in the country, but also contributes greatly to the country's economy as it remains a major employer to many Ghanaian households (MoFA, 2009).

However, there is a general belief among policy makers and researchers that Ghana's agricultural potential has largely remained untapped, with a widening gap between actual and potential yields. This is often blamed on low or non-adoption of agricultural

innovations by farmers with public research institutions often labelled as inefficient. Technology transfer and adoption have been identified as key to improving agricultural productivity, but funding of research and technology dissemination have also been a challenge to public research institutions and universities. It is against this background that research commercialization is strongly advocated by policy makers. To policy makers, research commercialization would improve private sector's access to research results from public institutions, generate more funds for research and development, increase national competitiveness, optimize the return on public research funding and usage of innovations as well as help public research institutions overcome their budgetary constraints (Karlsson, 2004; Ali, *et al.*, 2008).

Ghana has therefore taken steps to operationalize research commercialization and to ensure that there is benefit not only to the end users of research products but also to researchers. This has led to the enactment of laws on Intellectual Property (IP) rights. These IP laws include the Patent Act, 2003 (Act, 657), the Copyright Act, 2005 (Act 690), Trade Marks Act, 2004, (Act 664), Industrial Designs Act, 2003 (Act 660) and Geographical Indications Act, 2003 (Act 659) (Constitution of the Republic of Ghana, 1996). Ghana is also a member of the World Intellectual Property Organization (WIPO).

The findings from this research shall enrich the literature on commercializing research findings in Northern Ghana. The findings will also reveal whether farmers would be willing to pay for such findings or not.

1.5 Delimitations

Geographically, this study targeted the three Northern regions of Ghana: Upper East, Upper West and Northern region. The collection of data was delimited to 360 farmers, from approximately a farming population of 70% of a population of 4, 228,116 people.

The study districts were delimited to Bolga Municipal and Bongo district in the Upper East region, Wa East and Lambussie-Karni in the Upper West region and, Yendi Municipal and Tolon districts in the Northern region.

1.6 Limitations of the Study

The following points should be noted as limitations in interpreting the results of this study. First, the study was limited to farmers in Northern Ghana. As a result, some factors influencing their willingness to pay may be unique to them because of their socio-economic characteristics and farming systems, which may differ from farmers in the transitional, coastal and forest ecological zones of Ghana.

Secondly, the study includes questions about the total number of acres cultivated, total quantity of produce harvested, total quantity of produce consumed and sold as well as income from non-farm sources. Some farmers might have considered this information to be sensitive and therefore could have reported false figures or refused to respond.

Another limitation is the fact that currently, farmers are accessing “software” research innovations for free and might not have revealed the true amount they would have paid if

they were faced with reality. Likewise, researchers might also not have revealed their true willingness to accept because they were also not faced with reality. However, overtime, the stated values from researchers and farmers are likely to converge. The diffusion of information about innovations from research, as well as marketing effort can influence this convergence (Carson and Haneman, 2005). The convergence could also be brought about through the forces of demand and supply.

1.7 Basic Assumptions of the Study

Based on the rationale of WTP studies, it is assumed that the amount of money that researchers were willing to accept as payment for the various technologies, as well as the amount of money farmers were willing to pay for the various technologies, was a reflection of how much value they attached to a particular technology (Boadu, 1993). Thus the technology for which a larger amount was reported was the most valued or the most preferred. It is also assumed that farmers' WTP for research innovations truly reflect their ability to pay.

Research commercialization is assumed to improve quality of research, make innovations from research accessible to end-users (farmers) and to provide sustainable funding of research.

1.8 Organization of the Study

The study is organized into five chapters. Chapter two reviews literature. It looks at what has already been written on the topic in terms of theories and the overall goal of how the present study intends to address the weakness in the existing literature.

Chapter three contains the methodology employed in the study. The study area, sampling method, data collection and method of analyses, theoretical and empirical models are explained in this chapter. Chapter four analyses and presents the results. The summary, conclusion and policy recommendations as well as suggestions for future research are presented in chapter five.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Many studies have been done in the field of technology transfer through research commercialization and farmers' willingness to pay for innovations. This chapter therefore presents the theoretical and empirical literature relevant to the study.

The first section of the chapter presents a review of literature on the state of Ghana's agriculture. The second section explains the concept of innovation and the characteristics of an innovation that influence its adoption. The differences and similarities between research commercialization and academic engagement are dealt with in section three, while the fourth section gives an overview of funding research in developing countries. Section five looks at the arguments for open access to research findings as against research commercialization while section six presents a review of literature on factors influencing research commercialization and farmers willingness to pay for innovations from research. It also highlights some challenges facing research commercialization.

2.2 The State of Ghana's Agriculture

Ghana's agricultural share of GDP grew at an annual average rate of 5.1% from 1984 to 2006. Comparatively, Ghana has also performed better, in terms of growth in aggregate agricultural production and productivity, than countries often referred to as fast growing

agricultural economies, such as Brazil, China and Vietnam, since 1980. This happened as a result of increased productivity for land and labour coupled with increased area under cultivation as well as increased labour (ODI, 2011).

Subsequently, the increased agricultural productivity led to reduction in poverty levels across Ghana. Coulombe and Wood (2007) reported that urban poverty in Ghana was about 10% in 2008, compared with 51.7% in 1991/92. They reported poverty rate of 39.2% in rural areas in Ghana. This notwithstanding, there are still challenges in Ghana's agricultural sector. Ghana has natural conditions suitable for agriculture, yet the country remains highly dependent on food imports. Agricultural production currently meets only half of domestic cereal and meat needs and sixty percent of domestic fish consumption. Self-sufficiency in food production is achieved only in starchy staples such as cassava, yam and plantain, while maize and rice fall below demand (MoFA, 2007).

Some of the reasons why Ghana's food crop production remains below potential are not farfetched. Firstly, agriculture is still rain fed with production levels varying according to weather conditions (Wolter, 2008). Secondly, there are wide gaps between actual and potential yields (yield gaps) of major crops in Ghana. For example, it is estimated to be 42% for maize, 38-40% for rice, 46% for millet, 55% for cassava and 67% for yam (MoFA, 2010a). Research and technology application is therefore crucial to bridging the gap between actual and potential yields in Ghana. This cannot happen without the necessary investment in research and development.

Investments in agricultural research and development would not only enhance farm productivity, but also lead to poverty reduction. According to Thurlow *et al.* (2008), 1%

increase in crop yields in Africa, resulting from investments in agricultural research and development, leads to two million Africans lifted out of poverty. For very poor households, increased agricultural productivity would not only overcome hunger but also raise incomes nearly four times more effectively than growth in any other sector of an economy (Rajalahti, 2012). Therefore, the importance of investing in agricultural research and development cannot be overemphasized. Innovations do come about as products from research and development.

2.3 Meaning of Innovation

Innovation is the creation of something new, better or more effective processes, technology or ideas for the production of goods and services. However, innovation in itself is not enough. It is useful when it is adopted and used by markets, governments, and society (Bechdol, 2012). Innovation is the process by which individuals master and implement goods and services that are new to them. However, such goods and services might not be new to some other people somewhere (World Bank, 2006).

Technology is usually defined by economists as a stock of available techniques or a state of knowledge concerning a relationship between inputs and outputs (Colman and Young, 1989, as cited by Gregg, 2009). Technology development creates opportunities, benefits and efficiency gains for farmers resulting in competitive utilization of factors of production (Gurel, 1998).

Rogers (1995) defined a technology as an instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving a desired outcome. A technology

usually has two components, the hardware and the software aspects. The hardware aspect consists of the tool that embodies a material or physical object while the software component is the information-base for the tool. Rogers stated that the social embedding of the software component of a technology is usually less visible than its machinery or equipment and so technology is often understood in its hardware terms, especially agricultural technologies (Rogers, 1995). This concurs with the Food and Agriculture Organization's (FAO, 1997) categorization of technology into two: material technology, where knowledge is embodied into a technological product such as tools, equipment, agro-chemicals, improved plant varieties or hybrids, improved breeds of animals and vaccines, as well as knowledge-based technology, such as the technical knowledge, management skills, and other processes that farmers need to successfully grow a crop or produce animal products.

According to Rogers (2003), potential adopters evaluate an innovation based on their perception with regards to five attributes of the innovation: relative advantage, compatibility, complexity, trialability and observability. Relative advantage is the degree to which a technology is perceived as being better than a previous one, in terms of being less drudgery, time-saving, low initial cost, perceived lower risk and economically profitable.

Compatibility is the degree to which an innovation is perceived as consistent with the existing values, past experiences and needs of potential adopters. An innovation that is more compatible is less uncertain to the potential adopter, and fits more closely with the individual's life situation. This means that for a successful technology transfer, research

and extension must understand farmers' problems, learning needs, priorities, and opportunities as well as psychological, semantic and economic barriers to adoption (Mwangi, 1998).

Complexity is the degree to which an innovation is perceived as difficult to understand and use. Some innovations are clear in their meaning to potential adopters whereas others are not. Rogers noted that the complexity of an innovation, as perceived by members of a social system is negatively related to its rate of adoption.

Trialability is the degree to which an innovation may be put to practice or tried out on a limited basis. New ideas that can be tried in small amounts over a period of time, are generally adopted more rapidly than innovations that are not divisible. Some innovations are more difficult to divide for trial than others. The personal trial of an innovation is a way to give meaning to that innovation and to find out how it works under one's own conditions. The trialability of an innovation as perceived by members of a social system is positively related to its rate of adoption.

Observability is the degree to which the results of an innovation are visible to others. The results of some ideas are easily observed and communicated to others, whereas some innovations are difficult to observe or describe to others. The observability of an innovation, as perceived by members of a social system, is positively related to its rate of adoption.

The above mentioned perceived attributes of an innovation are important explanations of the rate of adoption of an innovation. Rate of adoption of an innovation is the relative

speed with which it is adopted and it is measured by the number of people who adopt an idea within a specified period, such as each year. Rogers also noted that other variables such as the type of innovation-decision, the nature of communication channels in diffusing the innovation at various stages in the decision process, the nature of the social system, in terms of norms, in which the innovation is diffusing and the extent of change agent's promotion efforts in diffusing the innovation, affect an innovation's rate of adoption. It is therefore important for researchers, in developing technologies for commercialization, to take into account these attributes of technology adoption proposed by Rogers and to undertake as part of commercialization promotion of these technologies.

2.4 Research Commercialization and Academic Engagement

Perkmann *et al.* (2013), defined commercialization as intellectual property creation and academic entrepreneurship. Markmann *et al.* (2008), contended that commercialization is a key example for generating academic impact because it constitutes immediate, measurable market acceptance for outputs of academic research. Whilst commercialization represents an important way for academic research to contribute to the economy and society, there are multiple other ways in which academic research from universities and research institutions are transferred (Salter and Martin, 2001). One of such ways is "academic engagement", defined as knowledge related collaboration by academic researchers with non-academic organizations (Perkman *et al.*, 2013). These interactions include formal activities such as collaborative research, contract research and

consulting as well as informal activities such as providing ad hoc advice and networking with practitioners (Perkmann and Walsh, 2008). Income from academic engagement is usually higher than that derived from intellectual property rights by universities and research institutions. Fewer academics are involved in commercialization relative to academic engagement. The performance of both academic engagement and commercialization could be looked at both individual and organizational or institutional levels. At the individual level, academic engagement is pursued by scientists who are well established and well-connected in the academic community. These scientists have longer years of experience and are mostly senior researchers. They have more social capital, more publications and more projects to implement. They also work more closely with industrial collaborators. For commercialization, the degree of complementarity with academic activities is less clear-cut; while commercialization tends to be positively related to scientific productivity, there is a contingent relationship with grants and contracts. Academic engagement is less embedded in organization than commercialization activities because it is mostly driven by individuals (Perkmann *et al.*, 2013). It is important to emphasize that whilst commercialization may be seen to be organizational, the productivity of individual scientists in the organization is critical. It is their individual productivity as scientists that will determine the overall organizational output such the number of property rights or patents emanating from the organization due to the hard work of individual scientists. Individual scientists' socio-economic characteristics and perceptions could therefore have an influence on research commercialization in an organization or institution. Research commercialization is increasingly seen as an additional source to funding research because of funding

challenges, visa-vi agricultural productivity challenges that still prevail, especially in developing countries.

2.5 Funding Research

It is estimated that more than two hundred and fifty million Africans are food insecure, though Africa's agriculture is one of the key sectors in the continent that has the potential and ability to lift millions of people out of poverty, food insecurity and hunger. However, for many years agriculture has stagnated, suffering from underinvestment, poor policies and incoherent strategies. African governments spend less than 7% of their national budgets on agriculture though 75% of poor people in Africa live in rural areas, whose mainstay is agriculture (Tibbett, 2011).

The Comprehensive Africa Agriculture Development Programme (CAADP), established as part of NEPAD (New Partnership for Africa Development, an economic development Programme of the Africa Union, AU), has an overall goal of eliminating hunger and reducing poverty through agriculture. To achieve this, African governments have agreed to increase public investments in agriculture by a minimum of 10% of their national budgets and to raise agricultural productivity by at least 6% per annum.

One of the key areas expected to receive the increased investment under CAADP is agricultural research. The rest are land and water management, market access, food supply and elimination of hunger.

During the period 2001-05, research and development at CSIR, accounted for about 10% of total government spending on agriculture, which was about 0.6% of total government expenditure, 0.4 of Agricultural Domestic Gross Product (AgGDP), and less than 0.2% of GDP. The bulk of government spending in the agricultural sector goes into recurrent expenditure, even though the share of development expenditure has been rising rapidly since the year 2000. This reflects a high level of donor support for development activities in the agriculture sector. It however raises questions on the sustainability of donor support to the agricultural sector and concerns about the government's capacity to rise to the challenge in the event of withdrawal of donor funds (Kolavalli et al, 2010).

One of the activities within the crops subsector that has enjoyed massive donor support is improved seed production activities. Sasakawa Global 2000 was instrumental in establishing a system of small scale seed producers, in the early 1990s. A GTZ West African Seed Network (WASNET) has supported the development of the commercial seed sector for more than a decade. Training activities for capacity building of agro-input dealers and seed producers have been sponsored by a USAID funded West Africa Seed Alliance (WASA). USAID-ADVANCE project has supported seed system development and several donors such as the African Development Bank and JICA funding various initiatives to improve access to rice seed. The MIDA project under the Millennium Challenge Account, also promoted the use of improved seed. AGRA has been funding plant breeding programmes in Ghana's National Research Institutes (Tripp and Mensah-Bonsu, 2013). Another area that has enjoyed massive donor support is capacity building of farmer based organizations (FBO), small and medium scale enterprises (SMEs) and agro-input dealers within the agricultural value chain. The aim of such capacity building

has been to develop the entrepreneurial and technical skills of small holder farmers and improve their access to research innovations, agro-inputs, credit and market access (AGRA/AVCMP, 2013).

The implementation of these projects has been holistic and stakeholder inclusive. Holistic in the sense that the research component of these projects has not only looked at coming out with improved seed, but also considered good agronomic practices, a composite of the use of improved seed: soil fertility management techniques, weed and pest management techniques, safe use of agro-chemicals and post-harvest techniques. Also, stakeholder inclusive in the sense that all the actors within the agricultural value chain are involved in the implementation of such projects. A good example was the Agricultural Value Chain Mentorship Project (AVCMP) sponsored by DANIDA through AGRA. It had the involvement of all the stakeholders within the agricultural value chain such as FBOs, agro-input dealers, aggregators, tractor service providers, processors and a few financial institutions. The AVCMP was implemented by CSIR-SARI, IFDC and GAABIC and supported by MoFA.

Some of these projects (such as the AVCMP) also developed modules for technology dissemination such as the use of radio, drama, cinema van, bulletins and posters as well as field demonstrations on integrated soil fertility management techniques in an effort to increase awareness level of research innovations and to encourage adoption of such innovations. As it is clear, the few mentioned projects that have a focus on agricultural research and many others, are sponsored by donors. The Government of Ghana has been

conscious of this and has taken steps in terms of policy formulation and regulation to ensure that there is some research commercialization.

Though spending in research and development was reported to have increased in sub-Saharan Africa by more than 20% from 2001 to 2008, most of this growth occurred in a few countries. Nigeria alone accounted for one-third of the increase. Agricultural research and development spending in Ghana more than doubled from 2000 to 2008 and dramatically after 2002 following a period of relative stagnation in the 1990s. In 2008, for example, Ghana spent $95 million on agricultural research and development compared with $41 million spent in 2002. This expenditure was largely as a result of salary costs at the institutes under the Council for Scientific and Industrial Research (CSIR). This reflects a policy environment in which the government of Ghana has recognized the importance of the agricultural sector, research and development in particular, in supporting the country's national development agenda (Flaherty *et al.* 2010).

The Pilot Programme Based Budget (PBB) of the Ministry of Food and Agriculture (MoFA) for 2013 to 2015 noted that funding for research is always difficult to access on a consistent and sustainable basis (MoFA, 2012). Therefore in developing a sustainable funding mechanism for agricultural research, the programme has proposed a number of options. These include:

1. Dialoguing with development partners and Ministry of Finance and Economic Planning to agree on appropriate funding mechanisms for agricultural research.
2. Dialoguing with private sector to fund agricultural research and

3. Facilitating the establishment of an agricultural research development and dissemination fund.

Given that the above mentioned options are the best in finding a sustainable funding mechanism to agricultural research, three years down the lane, there is no establishment of agricultural research development fund. Also, private sector contribution to funding agricultural research is still non-existent, and there is still no common position between the government of Ghana and her development partners on appropriate funding mechanisms for agricultural research. It is also not clear which private sector the programme is considering to fund agricultural research. Are farmers inclusive?

2.6 Open Access to Research Findings and Research Commercialization

Efforts have been made over the years by governments and policy makers across the globe to improve research outcome. This has led to increasing pressure on researchers both in the universities and research institutions to commercialize their research findings. At the same time, researchers have been encouraged to collaborate among themselves, share data and disseminate new findings quickly to improve the well-being of society and to make the impact of their research felt across all sectors of society. There are two folds to this increasing pressure on researchers to commercialize their findings. The first relates to the need for them to secure funding from sources other than government. The second is to position research as an engine of economic growth. This increasing pressure is no longer public statements from policy makers. It has been translated into policy statements

and mandates of universities and research institutions, with many of them now having technology transfer and commercialization units (Caulfield *et al.* 2012). Major funding organizations in the European Union, United Kingdom, United States of America, Canada and Spain put pressure on researchers to commercialize by offering them increased funding for research that has the potential for commercialization, providing assistance in obtaining intellectual property rights (IPRs) and putting in place contractual agreements mandating commercialization. Some funding agencies also favour limited access where research data are only available to those receiving the same funding or within the same region (Lévesque *et al.* 2014).

Commercialization of innovations does not only seek to reward innovators, but also seeks to achieve certain goals and missions for the general societal good. According to Shirvani (2007), the following issues are the main goals and missions of commercializing research results: increasing the market for knowledge based products, establishing and developing knowledge-based companies, providing the necessary regulations for creating learnedness-based work and income as well as realizing a chain from idea leading to finding commercial products in a country. Other goals of commercializing research results include increasing the supportive role of universities/research centres in paving the way to feed the findings of inventors and innovators into the market, supporting the relationship between scientific-technological centres and industry, coordinating universities/research centres' activities with research and technology priorities passed by legal officials, and increasing income level of universities/research centres.

Notwithstanding the various policies by governments and institutions aimed at promoting research commercialization, there are also proponents of open-sharing of scientific knowledge. Some proponents on open-sharing of scientific knowledge are the Organization for Economic Cooperation and Development (OECD), the International Organization of the Human Genome (HUGO) and UNESCO, among many others. These organizations consider scientific data as public goods whose value lies in their use (Caulfield, *et a*l. 2012).

Public funding of research, policies and practices vary from country to country, institution to institution as well as from one academic discipline to another. In promoting open access to research data as a means of improving scientific and social returns on public investment in research, OECD member countries have established international guidelines to be implemented at the national level by each member state. These international guidelines are supposed to foster the global exchange and use of research data to improve the overall efficiency of public funded research institutions. Open access to research data should be on equal terms for the international research community at the lowest possible cost. It should also be easy, timely, user friendly and preferably Internet-based (OECD, 2007).

The National Aeronautics and Space Administration (NASA) is another proponent of open science model. It has developed a plan on increasing access to the results of scientific research (NASA Plan, 2014). This is in response to a memorandum from the US Office of Science and Technology Policy (OSTP) directing all agencies with greater than $100 million in research and development expenditures each year to prepare a plan

for improving access to the public the results of federal funded research. Under this plan, NASA will promote full and open sharing of data with the research community, private industry, academia and the general public around the globe.

The plan is based on the following principles:

1. Effective data management has the potential to increase the pace of scientific discovery and efficiency in public funding of research;
2. Sharing and preserving data are central to protecting the integrity of science by facilitating validation of results and to advancing science by broadening the value of research data to disciplines other than the originating one to society at large;
3. Data management should be an integral part of research planning;
4. The degree to which research data needs to be shared or preserved varies across and within scientific disciplines; flexibility must be allowed for program specific needs/ requirements and consideration of benefits and cost, including preserving and promoting US competitiveness;
5. Propriety interests, business confidential information, intellectual property rights, and other relevant rights will continue to be recognized and appropriately protected; and
6. Protecting confidentiality and personal privacy are paramount, and no change will be made to existing policies that would reduce current protections.

It is unclear how researchers in practice could commercialize their innovations and at the same time promote open access to innovations. There seems to be a conflict between open access to innovation and innovation commercialization. However, this situation of

seeming conflict between open access to innovation and innovation commercialization might not exist nor comprise innovation commercialization. The open access policy only seeks to promote sharing of scientific data not innovations among the scientific community with the aim of improving quality and use of the data. The sharing and use of the data by scientists may lead to the development of innovations. Such innovations could then be bought by end-users leading to societal good. Scientific data, per se, may not make any meaning to the public. It is the product of the data which makes meaning and can be used by the public to improve their socio-economic circumstances.

2.7 Estimating the Cost Associated with the Provision of Agricultural Services

The unit cost of providing public goods is an important indicator that could be used to estimate the efficiency of service provision. In the agricultural sector, the unit cost of providing an innovation to farmers takes into account the outlay of expenditures that go into extending that particular innovation to the farmers. The outlay of expenditures include the direct operational cost (fuel, materials), cost of the time spent by the agricultural extension agents (annual salaries and benefits), and indirect or overhead costs including supervision. The unit cost is then derived based on the outputs (number of home and farm visits, number of farmers trained and number of demonstrations carried out) and the estimated costs, with the assumption that A.E.As spend equal time in achieving the different outputs. The unit cost is derived as the ratio of the total expenditure outlay to the output (Kolavalli *et al*. 2010).

In estimating the cost of providing agricultural technologies to farmers through farm and home visits, demonstrations and training in three regions of Ghana; namely, the Brong-Ahafo, Northern and Western regions, Kolavalli *et al.* (2010) found that the costs of service provided per farmer for the year 2006 were GH₵52.00 for the Brong-Ahafo region, GH₵64.00 for Northern region and GH₵93.00 for the Western region.

As Ghana envisages commercialization of innovations from research, calculating the cost of extension before provision to farmers and other end-users might not be applicable. This is because, according to computations from Kolavalli *et al.* (2010), you need to consider output as one of the elements in calculating cost of service provision, though their emphasis was on measuring the efficiency of service provision. What then can be done is to use computations from a previous year to determine the cost of service provision for the succeeding year. There are a number of challenges associated with this kind of cost computation. One, it is a top-bottom approach, taking into account costs such as salaries and benefits of civil servants (researchers and A.E.As) paid to provide a public service, cost of their time, among others, which may not be meaningful to users of the innovations. The use of contingent valuation then becomes necessary in valuing research and extension services in a research commercialization regime. This would give the users of agricultural technologies the opportunity to value such technologies based on their expected utility from the adoption of such technologies.

2.8 Factors Affecting Commercialization

Many factors have been hypothesized as having some influence on the commercialization of innovations from research in a number of studies. These factors have been categorized into individual, organizational, socio-cultural, statutory and economic factors (Fakur, 2007; Radfar *et al.* 2009; Mohammadi *et al.*, 2009; Nemati and Jamshidi, 2007; Bandaryan, 2009 as cited by Masudian *et al.* 2013) and outlined as follows:

Individual factors: These factors are taken as a scientist's informational knowledge about the nature and benefits of commercializing research results, his ability to solve problems and sense of research, as well as his knowledge and ability for entrepreneurship, market research and commerce. Other individual factors include a scientist's ability to think and analyze issues from creative ideas, curiosity to find answers to problems and having understanding of knowledge rules, laws and regulations for commercializing research results, his familiarity with needs, priorities and issues in market and industry sectors. Also, a scientist knowing the process of patenting and having commercialization experience have also been hypothesized as individual factors having some influence on the commercialization of innovations from research.

Organizational factors: the organizational factors take into account an institution manager`s familiarity with the process of commercializing research results, accessing knowledgeable counselors, their interest and perseverance in research, research officials' informational literacy and accessibility of technological means.

Socio-cultural factors: socio-cultural factors influencing research commercialization include the amount of cooperation and interaction among researchers, status and importance of research commercialization and existence of sense of competition among

researchers. The availability of investment funds for research, the existence of appropriate motives to commercialize research and having a knowledge-based economy in a country also influence commercialization of innovations from research. The level to which governmental and private sectors believe in researchers' research ability is also a socio-cultural factor that influences research commercialization.

Statutory factors: These factors include having appropriate policies about commercializing research results, the existence of structures and processes related to commercializing research at universities, the existence of laws, rules and accurate regulations, appropriate condition to patent inventions and having structured and statutory support to research institutions.

Economic factors: the economic factors include financial charts and regulations, researchers getting a share of the profits gained from commercialization and researchers' confidence about financial supports. It also include the amount of financial support, and financial cooperation of governmental organizations to research and technology and the financial support of investment funds, public and private from commercializing research results.

In assessing the level of current knowledge on academic engagement through a systematic review of a final selection of 36 articles from relevant research publications on academic engagement from 1980 to 2011, Perkmann *et al.* (2013), found individual, organizational and institutional determinants of both academic engagement and research commercialization. On the individual determinants, sex of researchers (male scientists), previous commercialization experience and scientific productivity were found to have a positive influence on research commercialization. For organizational determinants, the

authors found quality of university or research institution, organizational support, organizational commercialization experience and peer effects to positively influence research commercialization. Finally, for institutional determinants, they found applied discipline, life-science/ biotech and country-specific regulations to positively influence research commercialization.

For this study, our focus would be to look at the individual determinants of research commercialization in the field of agriculture, with special emphasis on agricultural innovations or technologies in northern Ghana. This is against the background that there is very little or no empirical research in this area, to the best of our knowledge. Ghana has also put in place the necessary regulations and policies in an effort to create the enabling environment for research commercialization. It would be interesting to study farmers' willingness to pay for innovations from agricultural research. Demand for innovations from research (extension services) can be evaluated through establishing the willingness to pay for the services among farmers. Willingness to pay (WTP) is a strong research approach that involves the targeted clients for potential services in establishing the preferences of the services proposed and the value the respondents are ready to pay. Willingness to pay for a service is the maximum amount of money an individual would be willing to pay for goods or services rather than do without it. In Agriculture, WTP studies have been used to evaluate demand and cost curves for extension services delivery through commercial agents (Nambiro *et al.* 2006; and Mwaura *et al.* 2010).

The debate to privatise extension services was muted due to wide spread corruption and inefficiencies in public corporations. Nonetheless, privatization has yielded desired results in the telecommunication and banking sectors. The questions that arise from

introduction of fee-paying extension system in subsistence dominated agriculture are whether it will lead to better efficiency, equity and effectiveness in serving both the subsistence and commercial farmers (Oladele, 2008).

Many factors have been identified as influencing farmers' willingness to pay for innovations. According to Oladele (2008), socio-demographic characteristics such as age, marital status, level of education, proportion of crop sold, land tenure, farm size and, years of experience in farming may affect farmers' willingness to pay for extension services. He noted that the younger farmers were willing to pay for extension services and also, the higher the level of education among farmers, the more they were willing to pay for extension services. He found that gender, farming experience and proportion of crop sold were inversely related to farmers' willingness to pay for extension services. This indicates that an increase in any of these variables will lead to a decrease in the probability of farmers' willingness to pay for extension services.

Ulimwengu and Sanyal (2011) noted that farmers' willingness to pay for one service is significantly and positively correlated with their willingness to pay for other services. Agricultural services can be viewed as complementary to one another, suggesting that the supply of agricultural services should be organized as a joint production system. They noted that farmers with prior access to agricultural and extension services were less willing to pay for agricultural services. Land ownership, regardless of the type of agricultural services, was found to increase farmers` willingness to pay. The level of farm income plays a major role in the decision of whether to pay for agricultural services, they also noted.

In assessing willingness to pay for extension services in Uganda among farmers involved in crop and animal production, Mwaura *et al.* (2010) found sex, age and level of education of farmers to influence their willingness to pay. Male headed households were more willing to pay for extension services than their female counterparts. Also farmers who had higher level of education were more willing to pay for extension services. Increasing age of farmers was associated with reducing willingness to pay for extension services for both crop and animal husbandry. Gang and Ping (2012) also found farmers' level of education, age, off-farm income, farm income and farm labour to positively influence their willingness to pay for information. They however found the awareness level of innovation by farmers which they called information satisfaction degree to negatively influence their willingness to pay for information. According to Gang and Ping when farmers own a lot of information, their willingness to pay for information would be weaker because they have a higher satisfaction degree.

A study by Falola *et al.* (2012) on willingness to pay for agricultural extension services by fish farmers in Kwara state of Nigeria, found stock size, nature of production (whether full-time or part-time fish farmers), level of education and age of farmers to be the significant factors affecting their willingness to pay. The level of education of the farmer, number of fish stock and full-time fish farming were found to have a positive influence on the farmers' willingness to pay for extension services. Increasing age of farmers was however found to have a reducing effect on their willingness to pay for extension services. In a similar study by Zakaria *et al.* (2014), age, on-scheme income and off-scheme income were found to positively influence farmers' willingness to pay for improved irrigation service from Bontanga Irrigation Scheme in Northern Ghana.

From all the studies reviewed on farmers' WTP for agricultural technologies, there is a key variable that is missing, which is free-ride. The effect of free-ride on farmers' WTP has not been estimated. This study attempted to do that.

Innovations from agricultural research are viewed by many as public goods. This is because most agricultural innovations tend to have the characteristics of public goods; non-excludability and non-rivalry. Non-excludability because consumers cannot be prevented from enjoying the innovation in question, even if they do not pay for it. Non-rivalry implies that the use of the innovation by one individual does not reduce the amount available to others. Because of these two peculiar characteristics, beneficiaries of public goods have no incentive to pay suppliers but rather a motive to "free-ride" (Sakuyama and Stringer, 2006). The free-rider problem occurs when those who benefit from resources, goods or services do not pay for them. This may result in either an under provision of those goods or service or could also result in over use (Baumol, 1952). Within a public good context, according to Olson and Cook (2008), free-riding emphasizes consumption based behaviour and refers to an under provision of resources and a failure by beneficiaries to reveal their true preferences for a public good.

Developing an accurate measure of free-riding has been problematic due to the broad definition given to the concept as well as the wide range of activities used to describe free-riding, and the latent nature of most free-riding (Olson and Cook, 2008). The authors used a Confirmatory Factor Analysis (CFA) to test for the relative importance of some free-riding indicators within collective organizations (Cooperatives). Free-riding was found to exist in the following areas : regular participation in communication activities by members, contacting the cooperative with concerns about its operations, monitoring of

management activities by members, general support given to the cooperative by members and consistent patronage of cooperative activities by members.

This study sought to establish the presence or otherwise of free-riding among willing to pay farmers from the sample for innovations from agricultural research. Thus will farmers be willing to pay for innovations knowing that they could later learn from friends and relatives who have paid for such innovations from researchers, for free.

2.9 Willingness to Pay Models

Valuation methods to assess the value of environmental services are normally classified into monetary and non-monetary measures. Monetary valuation methods are based on individual preferences (Sakuyama and Stringer, 2006). Valuation methods are based on either observed behaviour towards some marketed good with a connection to the non-marketed good of interest (revealed preference), or stated preferences in surveys, with respect to the non-marketed good (Navrud, 2000). According to Hoyos and Mariel (2010), the economic valuation of natural resources and other non-marketed goods and services using stated preference (SP) information has come to be known as contingent valuation (CV), given that respondents give value estimates in a survey based (contingent) on the information previously provided to them, mostly in a "construct" market or what is commonly referred to as hypothetical market. Non-marketed goods and services are those which may not be directly sold and bought in the market place such as agric. extension services on both hardware and soft-ware innovations (Merino-Castello, 2003).

Contingent valuation surveys measure the total value of the described good while revealed preference techniques, which are based on observed behaviour in private markets related to the environmental good, measure only direct use value. Revealed preference techniques are usually only capable of capturing the quasi-public value, which is the direct use portion of total value, because they rely on the availability of an implicit private market for a characteristic of the good in question. The availability of this market allows for potential excludability based on price. In contrast, passive use value can be seen as simply a special case of pure public good (Carson et al. 2001).

Different methods are employed in asking willingness to pay (WTP) questions in CV surveys. These include open-ended (OE), bidding game (BG), single-bound dichotomous-choice (1DC) and double-bound dichotomous-choice (2DC). Dichotomous-choice format is increasingly being used since it gives room for follow-up questions to increase the precision of value estimates respondents give in the survey (Ahmed and Gotoh, 2007). The single-bound dichotomous-choice (1DC) and double-bound dichotomous-choice can be merged into a single model of Dichotomous Choice (Ahmed and Gotoh, 2007), and according to Hanemann *et al.* (1991), the basics will still remain the same.

In the open-ended elicitation format, respondents are asked to state their maximum WTP for the resource or service to be valued. In the dichotomous or close-ended format, also known as referendum, respondents are asked for yes or no-answer concerning their willingness to pay on a single randomly assigned value. For example: “would you pay GH₵A for this item? In the case of double bounded-choice method, respondents are

asked additional question if they would pay a higher or lower amount (Ahmed and Gotoh, 2007; Hoyos and Mariel, 2010).

There have been a number of criticisms against these methods. Respondents find open-ended questions too difficult to answer because they are not used to paying non-marketed goods and services (Merino-Castello, 2003). Also, WTP might be underestimated in the open-ended question because respondents may not have information about the costs and benefits associated with the good or service of interest and also free-riding. There is also the "framing" or "anchoring" effect arising from the probability of accepting the bid level due to ignorance about true valuation (Kahneman *et al.* 1982; Ahmed and Gotoh, 2007). With the double-bounded dichotomous-choice model, there is the probability that exposure to the first offer would influence respondents to accept the follow-up offer. These problems make both open-ended and dichotomous choice formats susceptible to bias. This may lead to improper assessment of the good or service of interest, as the respondents might give answers without having adequate knowledge about the actual cost-benefit behind the evaluation. This bias could be avoided through a cost-benefit based dichotomous- choice method. In this method, additional information is provided on cost-benefit of the concerned good aimed at assisting the respondent in decision making (Ahmed and Gotoh, 2007).

The cost-benefit based dichotomous-choice method may not be appropriate for assessing farmers' WTP for innovations since his WTP is dependent on his expected marginal utility emanating from the adoption of the innovation. This marginal utility (i.e. increase in yield) is independent of the cost of the innovation. As perceived benefits of an

innovation is one of the influential factors for adoption, the cost associated with generating an innovation may not be the concern of the end users of that innovation. This method would also give room to gouging respondents in their WTP estimation. There is still the presence of "framing" effect in this method since apart from the benefit of the good, the cost of producing the good or service must form the basis for the respondent's WTP decision. This may "frame" the respondent's mind towards a particular amount sensitive to the cost compelling the respondent to overestimate his WTP.

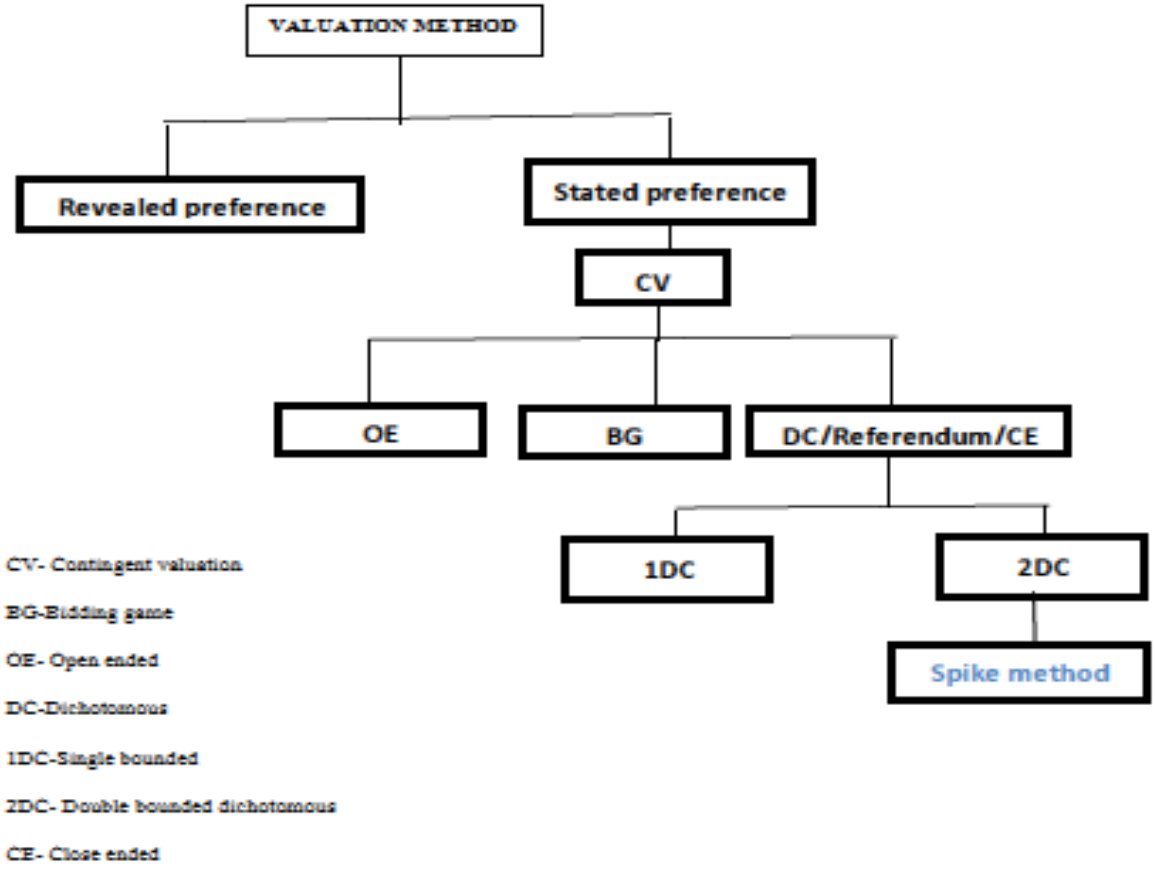
Merino-Castello (2003), also noted the following problems with regards to CV: only one attribute or scenario can be presented to a sample of respondents for valuation; it is a poor method for estimating consumer values because respondents are unlikely to provide an accurate response when presented with a hypothetical scenario; and CV may induce some respondents to behave strategically, particularly when public goods are involved.

These attacks on CV are not different from the usual attacks on survey based studies, which most of the time are not supported by empirical evidence. The overarching assumption in utility theory is that the consumer is rational and would still be rational when faced with decisions in a hypothetical market. Also farmers are generally familiar with benefits associated with agricultural innovations. The mere presentation of a hypothetical market to them would not make them give inaccurate responses. Also with proper elicitation format, the issue of strategic behaviour from respondents would be avoided.

This study therefore adopted the double-bounded dichotomous-approach, with a little variation added. The variation is that the respondents are first asked if they would be willing to pay. If the answer is positive, then they are asked again to state their minimum

and maximum WTP. With this technique, no offer is made to the respondent. Rather the respondent states his offer based on his expected marginal utility from adopting the innovation. This technique is a build-on to the spike model from Hanemann and Kanninen (1999). Figure 2.1 is an illustration of the stated preference and the various eliciting formats under it.

Figure 2.1 Eliciting Formats for Contingent Valuation



Source: Author's conceptualization based on Ahmed and Gotoh (2006), Hoyos and Mariel (2010) as well as Hanemann and Kanninen (1999)

The figure is based on the various literature reviewed on the eliciting formats. The revealed preference also has a number of eliciting formats under it. Since revealed preference is not the eliciting tool in this study, they are not shown in the figure.

2.10 Willingness to Accept (WTA) and Willingness to Pay (WTP)

In estimating the costs and benefits associated in extending large scale developmental projects to communities, economists had to evaluate the loss of environmental goods such as clean air and water, though such goods do not have direct market prices. People affected by such large projects were asked how much they would be willing to pay to avoid the environmental deterioration or how much they would have to be compensated to accept the same environmental deterioration. It was realized that WTA and WTP might differ if people selling their rights were wealthier than those buying them (Hoffman and Spitzer, 1993). But according to Willig (1976) such difference would be small, probably less than 5 percent under most circumstances. But this analysis was considered only applicable in the case of environmental goods. However, Willig's analysis led to further studies into respondents' WTP and WTA in a number of consumer surveys to value environmental commodities. Results from these surveys showed much divergence in value estimates between WTP and WTA. Various reasons have been assigned to have accounted for such a gap. These include strategic responses where the respondents lie to the surveyor in an effort to manipulate the outcome in accord with the respondents' true preferences, and information biases where the surveyors, may be unknowingly manipulate the responses by supplying information about the proposed program. Other reasons are instrument biases, where the surveyors questioning techniques mold the

results and errors produced by non-random sampling techniques (Hoffman and Spitzer, 1993, p.68).

In examining a wide range of experiments by economists and psychologists on testing whether WTA is substantially larger than WTP, Hoffman and Spitzer (1993) found evidence that WTA may substantially exceed WTP. According to them this results seems most likely to occur when consumers value consumption goods that are not repeatedly bought and sold. Many theories have been put forward in an attempt to explain why WTA is greater than WTP. These include the Prospect theory and the Endowment effect. Reviewing the works of Thaler, Kahneman and Kntsch, Hoffman and Spitzer (1993) concluded that losses have a larger impact than gains and that the prospect theory and the endowment effect provide useful social and scientific explanations for why WTA is greater than WTP. The explanation of the Prospect theory is that if an individual owns a good and is offered money to relinquish it, he regards the potential sale as the loss of the good. If he does not own the good, however, and is considering purchasing it, he views the potential purchase as a gain of the good. Because losses loom larger than gains, the individual will demand more to part with a good he already owns than he will be willing to pay for the same good. In that case, WTA exceeds WTP. The endowment effect is the difference between income earned and opportunity cost. In order to buy a good an individual must spend his earnings and to keep a good he already owns, an individual must forego the income he would have earned had he sold the good (opportunity cost). According to Thaler (1985), people weigh earned income more than opportunity cost, and that this difference in weighing cause people to "spend" opportunity cost more freely. Thus a person will be willing to pay more in opportunity cost to keep a good that he

already possesses than he would be willing to spend his earned income to acquire the good. In this case, also, WTA exceeds WTP (Hoffman and Spitzer, 1993, p.89).

Studies assessing the gap between WTA and WTP have largely been carried out in valuation studies on non-marketed environmental and resource goods. In such studies the same respondent is asked to state a minimum amount for which the individual is willing to sell an item and to state the maximum amount the same individual is willing to pay for the item.

This study would adopt the WTA and WTP valuations but for two different respondents: researchers and farmers. WTA would measure researchers' willingness to sell their innovations and WTP would measure farmers' willingness to buy innovations from research. A comparison would then be made to see if there are any gaps between WTA and WTP for the various agricultural technologies.

2.11 Challenges facing Research Commercialization

A study conducted by the United Nations Economic commission for Africa (ECA, 2013) on national experiences in the transfer of publicly funded technologies in Ghana, Kenya and Zambia found the following challenges to research commercialization: lack of skills to successfully commercialize research outputs, institutions considering their own research not relevant to industry, lack of funding for commercializing research and lack of private sector interest in new technologies. Other identified challenges are lack of clear guidelines and policies on research commercialization, no economically viable research

outputs, commercialization not being considered as a priority area by institutions, and last but not the least, limited time allocation to commercialization activities by research institutions.

The study suggested a number of solutions to overcoming the challenges facing research commercialization. Firstly, provision of clear policies, guidelines and incentives for protection, ownership and transfer of publicly funded research (though this is being implemented by many governments in Africa, including Ghana) and making technology transfer as a core activity of research institutions. Secondly, training of some members of staff in technology transfer arrangements, recruiting skilled technology transfer managers, encouraging the formation of technology transfer and business development units and provision of funding specifically for technology transfer activities.

It is important to notice that the above mentioned challenges exist because of two reasons, one is lack of funding and two, a complete dichotomy or absence of link between research institutions and end users of products from research. A complete dichotomy in the sense that research institutions are not sure if their products meet the needs of industry, on one hand, and on the other hand, there is reported lack of interest by the private sector in new technologies. This is largely the case where many innovations are developed but not adopted by end-users.

A study by Tanha *et al.* (2011) on commercialization of university research and innovations in Iran, found the following as challenges: products from research were not completely based on customer needs, lack of solid rules and regulations for protecting Intellectual Property (IP) rights, inadequate link between researchers and regional as well

as global markets due to lack of IP rights, lack of appropriate evaluation of ideas and innovations in a national entity, and limited or no venture capital for investment in new technologies. Some of the solutions proposed in their study included developing a blue-print on research commercialization in which research priorities are highlighted, putting in place a regulatory structure on IP rights, financing research from both governmental and non-governmental budgets and researchers having their share from benefits accruing from innovations commercialization activities. What is also missing is the contribution from the private sector and other end users of innovations from research as another alternative to research funding, besides financing research from government and non-governmental sources, which in most cases very inadequate.

Other challenges exist in the form of conceptual framework for promoting and communicating innovations and institutional bottlenecks, especially in developing countries. Aubert, (2004) argued that even though more attention is being paid to the promotion of innovation in developing countries, there is no solid conceptual framework from which appropriate policies can be developed in promoting and communicating innovations. The author examined eight thematic areas in developing a conceptual framework for promoting innovation in developing countries. These include understanding innovation climate in developing countries, innovation needs and opportunities, appropriate strategies at national level, efficient support for innovators, challenging global trends and policy responses, cultural specificities and innovation policies, and evaluation of innovation systems and policies.

In assessing the institutional bottlenecks of the agricultural sector with respect to research and extension development in Ghana, Asuming-Brempong *et al.* (2006), reviewed a number of issues that are critical to extension development. These include institutional characteristics of research and extension (levels of decentralization and governance structure as well as the technical ability of these institutions) and analysis of the compliance process (such as the techniques for disseminating relevant extension messages and the incentive systems in place for motivating extension agents). Others include an assessment of the performance of the research and extension system (in terms of technology packages available and the mode of delivery of the extension message) and an assessment of the household or farm outcomes (based on the changes that have occurred in the practices of farm households in response to the extension messages).

The challenges identified are institutional and may require policy direction, legal and regulatory frameworks to enhance research commercialization. The mere presence of policies and regulations might not be enough to propel research commercialization. The mindset of the researcher or his perceived challenges towards research commercialization and perceived solutions to overcoming such challenges, are equally important to the success of research commercialization. Also equally important is the availability of market or demand for innovations from research in the context of a specified research discipline. What this study also seeks to do is to empirically assess researchers' perceived challenges in the field of agricultural research towards commercialization and their perceived solutions. Additionally, this study seeks to find out whether there is the potential for research commercialization in northern Ghana.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter describes the economic theory behind contingent valuation for both willingness to pay and willingness to accept payment. It also describes the study area and the sampling procedure, methods of data collection and analysis as well as the theoretical and empirical models of the study.

3.2 Economic Theory of Contingent Valuation (CV) for WTP and WTA

The goal of a CV study is to measure an individual's monetary value for some item, q (Carson and Hanemann, 2005). The utility function of an individual is defined by quantities of market commodities x_1 and q_1 and this is given as

$$U = u(x, q) \quad (1)$$

Corresponding to this direct utility function is an indirect utility function given as

$$U = u(p, q, y) \quad (2)$$

where p is the vector of the prices of the market commodities and y is the person's income. We make the conventional assumption that U(x, q) is increasing and quasi-concave in x, which implies that U (p, q, y) satisfies the standard properties with respect to p and y, but we make no assumptions regarding q. If the agent regards q as a "good", U(x, q) and U(p, q, y) will both be increasing in q, if he regards it as a "bad",

U(x, q) and U(p, q, y) will both be decreasing in q; if he is indifferent to q, U(x, q) and U(p, q, y) will both be independent of q.

The act of valuation implies a contrast between two situations: a situation with the item and one without it. We interpret what is being valued as a change in q. specifically, suppose that q changes from q^0 to q^1, the person's utility changes from $U^0(p, q^0, y)$ to $U^1(p, q^1, y)$. If he regards this change as an improvement, $U^1>U^0$; if he regards it as a change for the worse, $U^1<U^0$; if he is indifferent, $U^1=U^0$. The value of the change to him in monetary terms is represented by the two Hicksian measures, the compensating variation C and the equivalent variation, E.

The compensating variation (C) and the equivalent variation (E) are respectively given as:

$$U(p, q^1, y - C) = U(p, q^0, y) \quad (3)$$

And the equivalent variation E, which satisfies

$$U(p, q^1, y) = U(p, q^0, y + E) \quad (4)$$

If the change is regarded as an improvement, C>0 and E>0; in this case, C measures the individual's maximum WTP to secure the change, while E measures his WTP to avoid it. If he is indifferent to the change, C = E = 0. Conversely, if the change is regarded as a loss, C<0 and E<0.

Compensating variation (C) and equivalent variation (E) could be respectively written as functions:

$$C = C(q^1, q^0, p, y) \quad (5)$$

$$E = E(q^1, q^0, p, y). \quad (6)$$

The WTP is defined as:

$$WTP(q^1, q^0, p, y) = \begin{cases} C(q^1, q^0, p, y) \text{if } C \geq 0 \\ -E(q^1, q^0, p, y) \text{if } C \leq 0 \end{cases} \quad (7)$$

The WTA function, WTA (q^1, q^0, p, y) is defined analogously. The goal of a CV study is to measure one or another of these valuation functions – either the entire function or a particular point on the function. For simplicity, we assume that the change is an improvement ($C \geq 0$) and we focus on the measurement of WTP.

Let $y = m(p, q, u)$ be the expenditure corresponding to the direct utility function U(x, q) and the indirect utility function U(p, q, y); which should be increasing in U and non-decreasing, concave and homogenous of degree 1 in p. It is decreasing in q if q is desired, increasing in q if q is a bad, and indifferent of q if the individual is indifferent to q. In terms of the expenditure function, the compensating and equivalent variations are defined as

$$C = m(p, q^0, U^0) - m(p, q^1, U^0) \quad (8)$$

$$C = y - m(p, q^1, U^0) \quad (9)$$

And

$$E = m(p, q^0, U^1) - m(p, q^1, U^1) \quad (10)$$

$$E = m(p, q^1, U^1) - y \quad (11)$$

We impose the restriction that

$$\lim_{y \to 0} U(p, q, y) = -\infty \qquad (12)$$

3.3 The Study Area

The study was carried out in Northern Ghana. Northern Ghana comprises the Upper West, Upper East and Northern Regions. It lies roughly north of the lower Black Volta River, which together with its tributaries; the White and Red Voltas and the Oti and Daka rivers drain the area. Northern Ghana shares international boundaries with Burkina Faso to the north, Togo to the east and Cote d`Ivoire to the lower south west.

According to the Ghana Statistical Service (GSS, 2010), the three northern regions have a total population of 4,228,116, representing 17.1 percent of Ghana's total population. Specifically, the Upper West region represents 2.8 percent of the total population of Ghana, 4.2 percent for Upper East region and Northern region has a share of 10.1 percent. Agriculture is the predominant economic activity in the three regions. In the Northern and Upper West regions, more than 70 percent of the economically active population is engaged in agriculture, forestry and fishing activities.

Northern Ghana has a single rainy season that begins in May and ends in October. The amount of rainfall recorded annually varies between 750mm and 1050mm. The rainfall pattern is erratic and irregular in terms of distribution and amount. The dry season starts in November and ends in March/ April with maximum temperatures occurring towards

the end of the dry season. The temperature in the region is between 15^0C at night during the hamattan and 40^0C in the day during the hot season.

3.4 Sampling Procedure

Selection of sampling methods and sample size for the study was guided by suggestions from Hair *et al.* (2007), Roscoe (1975) and Stutely (2003). According to Hair *et al.* (2007), representative sampling is obtained by pursuing a set of well-defined procedure which include defining the target population, selecting a sampling method and determining the sample size. Roscoe (1975) suggested that sample sizes larger than 30 and less than 500 are appropriate for most research. Stutely (2003) also suggested a minimum number of 30 as appropriate for statistical analysis. Irrespective of these suggestions, it is important to note that sample size selected must be representative enough.

Subsequently, a total of six districts were randomly sampled for the study; two from each of the three northern regions of Ghana. Six communities were then selected from each district and ten households from each of the selected communities through simple random sampling technique. In total, three hundred and sixty households were interviewed with the use of semi structured questionnaires. Fifty one researchers were also randomly selected and interviewed from two purposively selected institutions: University for Development Studies (U.D.S.) and Savannah Agricultural Research Institute (SARI) based on their specialization in the following areas of agricultural technology: improved

seed varieties (early maturing, high yielding, drought- resistant, striga-resistant, improved palatability), recommended seed and fertilizer rates, recommended planting distances, soil fertility management practices, pest and disease control, post-harvest techniques and improved soil and water conservation practices. Both institutions also have their mandates covering the three regions of northern Ghana.

Table 3.1 Distribution of farmers sampled; by regions and districts

REGION	DISTRICT	NUMBER OF FARMERS
Upper East	Bolga Municipal	120
	Bongo	120
Upper West	Wa East	120
	Lambussie-Karni	120
Northern Region	Yendi	120
	Tolon	120
TOTAL	**6**	**360**

The list of communities for the districts are contained in appendix 3.

3.5 Data Collection

The main source of data for the study was primary data, which was collected using semi-structured questionnaires. The questionnaires were administered to both farmers and researchers. Each questionnaire contained a hypothetical market.

The questionnaire for the farmers had a number of sections. The first section was designed to collect information on farmers' socio-economic characteristics such age, sex, primary and secondary occupation, household size, educational status, membership of an FBO, number of years in farming, whether a farmer was a native or not, number of fields and total number of acres he/she cultivated.

The second section gathered data on quantities of agro-inputs used for the cropping season including fertilizer use, herbicides and seed for some selected crops. It also included output quantities, quantities sold and unit prices of output which helped us to estimate respondent's farm income during the 2013/14 cropping season.

The third section of the survey covered information on farmers who had other sources of income besides farming by looking at a number of economic activities that they were engaged in, including remittances, and how much revenue was generated from each activity for the 2013/14 cropping season. The last section of the survey elicited farmers' willingness to pay for agricultural technologies. The method of elicitation used was the spike model. With the spike model, researchers and famers were first asked whether they were willing to sell and willing to pay for research innovations, respectively. If yes,

respondents were asked to state their minimum and maximum values for the various innovations.

The second set of data was collected on researchers. The design of the first section of the questionnaire took into account age of researchers, primary and secondary occupation, highest academic qualification, membership of any professional body, years of experience, and number of publications as well as researchers' areas of specialization. The second section covered information on major sources of research funding in northern Ghana, whether such major funding sources had witnessed a decline, increase or have remained same during the past five years, as well as information on percentage of decline or increase.

The third section gathered information on the sale of research output from researchers during the last five years, the buyers of such research output, and the factors influencing research commercialization. The last section of the survey asked researchers whether they were willing to commercialize their research innovations, and the values they were willing to accept as payment for such innovations.

3.6 Data Analysis

Data collected were analysed using both descriptive and inferential statistics. Data on the socio-economic characteristics of both farmers and researchers were presented in the form of bar graphs and frequencies using SPSS and Excel. Amounts at which farmers were willing to pay and researchers willing to sell the various technologies were

presented in tables and compared. The empirical models for willingness to pay and willingness to sell were estimated using STATA 13.

3.7 Conceptual Framework

The conceptual base for this study lies in the need for private participation in funding agricultural research through commercialization of innovations from research. Also, the need for agricultural research to move from "business-as-usual" to be results-oriented and demand-driven academic discipline yielding financial rewards to scientists for their ingenuity and hard work as well as increased income to farmers through increased productivity as a result of adoption of innovations from research.

According to Holden and Shiferaw (2002) and Ulimwengu and Sanyal (2011), willingness to pay is modeled as a sacrifice of current income in order to sustain or increase agricultural productivity in the future. Therefore, Expenditure function is used to estimate WTP for improvement in the quality of a resource. The minimum expenditure level (e) required to achieve the initial utility level is given by an expenditure function as

$$e = (p, EU_0, F_0) \qquad (13)$$

where p is the vector of prices, o is the current expected utility level, and Fo is the set of old agricultural services and farm characteristics. This means the amount of money a farmer spends in acquiring improved agricultural innovations is a function of prices, expected utility as well as agricultural services and farm characteristics.

It follows that the willingness to pay in order to sustain current productivity is given by

$$WTP = (p, EU_0, F_0) - e(p, EU_0, F_1) \quad (14)$$

Where WTP is the amount at which the household feels indifferent between the expected marginal utility under the old set of technologies and the discounted expected marginal utility of the change in future incomes as a result of the new set of agricultural technologies; F_1 is the new set of agricultural services and farm characteristics.

Researchers' willingness to commercialize innovations can be analysed using willingness to accept (WTA) as proxy. WTA measures how much a respondent is willing to accept as compensation for a loss of a good or service.

Contingent valuation tends to quantify the value consumers assign to products using a hypothetical purchasing situation in which they have to answer how much money they would be willing to pay for a given product, or if they would be willing to pay for a certain price premium (Carmona-Torres and Calatrava-Requena, 2006).

3.8 The Theoretical Model

3.8.1 The Probit Model

The regressand, farmers` willingness to pay for agricultural technologies, is qualitative in nature. This response variable or regress and can only take two values: 1 if the farmer is willing to pay a technology and 0 if he/ she is not willing to pay. In a model where the response variable is qualitative, the objective is to find the probability of an event

occurring. Qualitative response regression models are often referred to as probability models. The usual ordinary least square regression (OLS) cannot be used because of the problems of non-normality of the error term (μ_i), heteroscedasticity of the error term and possibility of the probability value lying outside the 0-1 range. The cumulative distribution function (CDF) can be used to model regressions where the response variable is binary. One of the CDFs commonly selected to represent the 0-1 response is the normal or probit model (Gujarati, 2004).

Following Gujarati (2004), to motivate the probability model, the decision of the i_{th} farmer's willingness to pay for agricultural technology or not depends on an unobservable utility index I. This utility index is a latent variable which is determined by a number of explanatory variables. The index, I_i is expressed as

$$I_i = \beta_1 + \beta_2 X_i \qquad (15)$$

In establishing the relation between the unobservable utility index and the actual decision making on willingness to pay, a threshold level of the utility index is assumed, say $*$.

$$\text{if } I_i > I_i^*, \qquad I = 1$$

$$\text{if } I_i < I_i^* \qquad I = 0$$

Given the assumption of normality, the probability that $*$ is less than or equal to can be computed from the standardized normal CDF as

$$P_i = P(Y = 1|X) = P(I_i^* \leq I_i) = P(Z_i \leq \beta_1 + \beta_2 X_i, \ldots\ldots\ldots \beta_n)$$

$$= F(\beta_1 + \beta_2 X_i \ldots\ldots\ldots\ldots \beta_n X_n) \qquad (16)$$

Where $P(Y = 1|X)$ means the probability that an event occurs given the values of the explanatory variables and where is the standardized normal value, i.e. $Z \sim N(O, \sigma^2)$

F is the standard normal CDF. Taking the inverse of the CDF gives

$$I_i = F^{-1}(I_i) = F^{-1}(P_i) = \beta_1 + \beta_2 X_i \dots\dots\dots\dots \beta_n X_n \quad (17)$$

Where F^{-1} is the inverse of the normal CDF.

Running a separate estimation for determining willingness to pay for different agricultural technologies is likely to yield biased estimates especially in a situation where the willingness to pay for one agricultural technology significantly correlates with the willingness to pay for other technologies (Ulimwengu and Sanyal, 2011). Therefore, in this study, the probit model is used to estimate researchers` willingness to sell agricultural technologies while the multivariate probit model is also used to estimate farmers` willingness to pay for different agricultural technologies.

Evaluation of probit –model likelihood functions requires calculation of normal probability distribution functions. There are available statistical software packages that give accurate calculations for univariate and bivariate normal probability distribution functions, such as Stata and SPSS. However, accurate functions do not exist in these software packages to evaluate multivariate normal distributions.

Following Capellari and Jenkins (2003), the multivariate probit is given as

$$y_{im}^{*} = \beta X_{im} + \varepsilon_{im}, m = 1\dots\dots\dots\dots\dots\dots\dots\dots\dots M \quad (18)$$

$y_{im} = 1$ if $y_{im}^{*} > 0$ and 0 otherwise $\varepsilon_{im}, m = 1 \ldots \ldots \ldots \ldots M$ are error terms distributed as multivariate normal, each with a mean of zero, and variance-covariance matrix V, where V has values of 1 on the leading diagonal and correlations.

Capellari and Jenkins (2003) noted that the model has a structure similar to that of a seemingly unrelated regression (SUR) model, except that the dependent variables are dichotomous.

The Geweke-Hajiuassiliou-Keane (GHK) smooth recursive conditioning simulator is used for estimating the multivariate probit model.

If Y^{i}_{j} denote farmer *I*'s binary response outcome associated with each *j* type of agricultural technology, for *j* = 1 such that is 1 if farmer *I* is willing to pay for agricultural technology *j* and 0 otherwise. Ulimwengu and Sanyal (2011) showed that the multivariate probit model can be specified as a linear combination of deterministic and stochastic component:

$$y_j^i = x'\beta_j + \varepsilon_j \qquad (19)$$

Where x = (1, x, ..., x_p) is a vector of **p** covariates, which do not differ and $\boldsymbol{\beta}_j$ = ($\boldsymbol{\beta}_{jo}$, $\boldsymbol{\beta}_{jp}$) is corresponding vector of parameters to be estimated. The error term $\mathscr{E}_j$ consists of those unobservable factors affecting the marginal probability of WTP for a type of j agricultural technology. They added that each $\mathscr{E}_j$ is drawn from a J-variate normal distribution with zero conditional mean and variance normalized to unity (for parameter identification): $\mathscr{E} \sim N(O, \Sigma)$ with the variance covariance matrices given by:

$$\Sigma = \begin{bmatrix} 1 & P_{12} & \dots\dots P_{1j} \\ P_{21} & 1 & \dots\dots P_{2j} \\ P_{j1} & P_{j2} & \dots\dots 1 \end{bmatrix} \quad (20)$$

The off-diagonal elements in the covariate matrix P_{sj} represent the unobserved correlation between the stochastic component of the s^{th} and the j^{th} types of the agricultural technology (innovations).

3.8.2 Empirical Model of the Probit

First, our probit model for estimating researchers' WTA payment for their innovations is constituted as

$$Y_t = \beta_0 + \beta_1 Age + \beta_2 Mem + \beta_3 Exp + \beta_4 No.Pub + \beta_5 Non.Pro. + \beta_6 Dep.Sal + \beta_7 Nec.Pub + \varepsilon_t \quad (21)$$

where

Yt = Researchers' WTA payment for his innovations

X_1 = Age of researcher

X_2 = Researcher's membership to a professional body a respondent

X_3 = Number of years a researcher has spent in agricultural research

X_4 = Number of publications of a researcher

X_5 = Researcher' perception about technology transfer being profitable or not

X_6= Researcher's source of salary

X_7= Researcher's promotion being dependent solely on a certain number of publications

$\mathscr{E}$ = Sample Error Term

3.8.3 Empirical Model of the Multivariate

Our multivariate probit model for estimating farmers' WTP for innovations from research is constituted by eight equations:

$$Y_{i1}^{*} = X_{i1}\beta_1 + \mathcal{E}_{i1} \quad \text{(22a)}$$

$$Y_{i2}^{*} = X_{i2}\beta_2 + \mathcal{E}_{i2} \quad \text{(22b)}$$

$$Y_{i3}^{*} = X_{i3}\beta_3 + \mathcal{E}_{i3} \quad \text{(22c)}$$

$$Y_{i4}^{*} = X_{i4}\beta_4 + \mathcal{E}_{i4} \quad \text{(22d)}$$

$$Y_{i5}^{*} = X_{i5}\beta_5 + \mathcal{E}_{i5} \quad \text{(22e)}$$

$$Y_{i6}^{*} = X_{i6}\beta_6 + \mathcal{E}_{i6} \quad \text{(22f)}$$

$$Y_{i7}^{*} = X_{i7}\beta_7 + \mathcal{E}_{i7} \quad \text{(22g)}$$

$$Y_{i8}^{*} = X_{i8}\beta_8 + \mathcal{E}_{i8} \quad \text{(22f)}$$

$Y_{i1}^{*} - Y_{i8}^{*}$ denotes farmers' willingness to pay for improved seed, soil fertility improvement techniques, weed and pest control methods, safe use of agro-chemicals,

crop disease identification and control measures, farm management and record keeping and post-harvest techniques, respectively. $X_{i1}, X_{i2}, X_{i3}, \ldots\ldots\ldots X_{i8}$ represent the socio-demographic characteristics (age, educational status, nativity, free-rider, number of acres a farmer cultivated, non-farm income, farm income and number of contacts a respondent had with an extension agent within a year) affecting the choices of the i^{th} farmer. β_1, β_2, β_3, β_4, β_5, β_6, ε_7 and β_8 are parameters to be estimated. $\varepsilon_{i1}, \varepsilon_{i2}, \ldots\ldots\ldots\ldots\varepsilon_{i8}$ are error terms attributed as multivariate normal:

$$\begin{bmatrix}\varepsilon_{i1}\\ \varepsilon_{i2}\\ \varepsilon_{i3}\\ \varepsilon_{i4}\\ \varepsilon_{i5}\\ \varepsilon_{i6}\\ \varepsilon_{i7}\\ \varepsilon_{i8}\end{bmatrix} \sim N(O,\sum) \; of \; which \begin{bmatrix} 1 & P_{12} & P_{13} & P_{14} & P_{15} & P_{16} & P_{17} & P_{18}\\ P_{21} & 1 & P_{23} & P_{24} & P_{25} & P_{26} & P_{27} & P_{28}\\ P_{31} & P_{32} & 1 & P_{34} & P_{35} & P_{36} & P_{37} & P_{38}\\ P_{41} & P_{42} & P_{43} & 1 & P_{45} & P_{46} & P_{47} & P_{48}\\ P_{51} & P_{52} & P_{53} & P_{54} & 1 & P_{56} & P_{57} & P_{58}\\ P_{61} & P_{62} & P_{63} & P_{64} & P_{65} & 1 & P_{67} & P_{68}\\ P_{71} & P_{72} & P_{73} & P_{74} & P_{75} & P_{76} & 1 & P_{78}\\ P_{81} & P_{82} & P_{83} & P_{84} & P_{85} & P_{86} & P_{87} & 1 \end{bmatrix} \quad (23)$$

Each with a mean of zero, and variance-covariance matrix V, where V has a value of 1 on the leading diagonal and correlations $pj_k = pk_j$ as off-diagonal element.

If $\varepsilon_{i1}, \varepsilon_{i2}, \varepsilon, \varepsilon_{i4}, \varepsilon_{i5}, \varepsilon_{i6}, \varepsilon_{i7}$ and ε_{i8} are independent of each other, the results from the multivariate probit model would be identical to those from a univariate probit model. P_j is the correlation coefficient between any pairing of the model , showing the degree of correlation of the values of the residuals of any two variables. $Y^*_{i1}, Y^*_{i2}, Y^*_{i3}, Y^*_{i4}, Y^*_{i5}, Y^*_{i6}, Y^*_{i7}$ and Y^*_{i8} are the latent variables while $Y_{i1}, Y_{i2}, Y_{i3}, Y_{i4}, Y_{i5}, Y_{i6}, Y_{i7}$ and Y_{i8} are observable and dichotomy variables. The relationship between the observable and latent variables is:

$$Y_{ij}\begin{cases}1 & if\ Y^*_{ij} \geq 0\\ 0 & if\ Y^*_{ij} < 0\end{cases} \; i = 1, \ldots\ldots\ldots\ldots n, j = 1,2,3,4,5,6,7,8$$

With the multivariate probit model, Cappellari and Jenkins (2003) pointed out that the log-likelihood for a sample of N independent observations is given by:

$$L = \sum_{i=1}^{N} w_i \, log\phi_8(N_i, \Omega) \qquad (24)$$

Where w_i is an optional weight for observation, I = 1,……,N, and $\phi_8(.)$ is the multivariate standard normal distribution with arguments N_i and Ω, where,

$$Ni = \left(K_{i1}\beta'_1 X_{i1}, K_{i2}\beta'_2 X_{i2}, K_{i3}\beta'_3 X_{i3}, K_{i4}\beta'_4 X_{i4} \ldots\ldots\ldots K_{i8}\beta'_8 X_{i8}\right) \qquad (25)$$

With $K_{ik} = 2Y_{ik} - 1$, for each I, k = 1,……., 8.

Matrix Ω has constituent elementsΩ_{jk}, where $\Omega_{ij} = 1$ for j = 1,……., 8.The log-likelihood function depends on the multivariate normal distribution function, $\phi_8(.)$.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the results and discussions of the study based on the data collected from 51 researchers and 360 farmers. The chapter has five sections. The first section looks at the socio-economic characteristics of researchers. The second section considers funding options for research activities, sale of research output and researchers stated willingness to accept (WTA) payments for their innovations, with accompanying reasons for their choices. The third section looks at the socio-economic characteristics of the farmers, access to credit and quantities of input used as well as farmers' stated willingness to pay for innovations. The fourth section discusses results on the valuation of the given technologies by both researchers and farmers. The last section presents the empirical estimation results of both the probit and the multivariate (MV) probit models.

4.2 Descriptive Statistics

This section presents the descriptive statistics emerging from the findings. Descriptive results form the basis of quantitative data analysis and offer data summaries across observations (Trochim, 2006).

4.2.1 Researchers' Socio-Economic Characteristics

Table 4.1 shows the socio-economic characteristics of researchers. The mean age of the researchers was 41 years. Their ages ranged from 25 to 58 years.

On the type of occupation of a researcher, 35% of them were research scientists followed by 20% being research assistants. About 24% were University lecturers, 8% were laboratory technicians and 13% were agricultural extension officers.

The highest academic qualification of each researcher was considered. About 28% of the researchers interviewed were PhD holders, 39% were MSc/ MPhil holders and the remaining 33% were BSc holders. PhD qualification is generally considered fundamental to the management of high quality research, effective communication with policy makers and increasing an institution's chances of securing competitive funding (Beintema and Stads, 2014). Beintema and Stads reported a 20% share of agricultural researchers with PhD degrees for 2011 for sub-Sahara Africa. Thus there should be an affirmative action by the universities and research institutions to increase the number of researchers with PhD qualification.

More than half (52.9%) of the respondents did not belong to any professional body whilst the remaining 47.1% were members of various professional bodies such as British Soil Science Society, Weed Science Society of America, Ghana Institute of Horticulturalists and Research Staff Association of Ghana, among others. The highest percentage of the researchers interviewed (33%) had 2-5 years working experience in the field of agricultural research. Some 27% of the respondents had between 6-10 years working experience. Some 31% of respondents had between 11-20 years working experience and

the remaining 8% had a working experience of 21-26 years. The sample had a mean of 10 years of working experience.

Table 4.1 Researchers' Socio-economic Characteristics

VARIABLES	FREQUENCY (n=51)	PERCENTAGE	MEAN
AGE RANGE (YEARS)			41
25-35	16	31.3	
36-45	16	31.3	
46-58	19	37.4	
OCCUPATION			
Research Scientist	18	35	
University Lecturer	12	24	
Research Assistant	10	20	
Laboratory Technician	4	8	
Agricultural Extension	7	13	
Membership of Association			
Yes	24	47.1	
No	27	52.9	
YEARS OF EXPERIENCE			10
2-5	17	33	
6-10	14	27	
11-20	16	31	
21-26	4	8	
RESEARCHERS' QUALIFICATION			
PhD	14	28	
MSc/ MPhil	20	39	
BSc	17	33	
Researcher's number of publications			6.5
No Publication	15	29	
1-5	13	26	
6-10	9	18	
11 and above	14	28	
Source of salary and emoluments	39	77	
GoG	12	23	
Project funds			

Source: Computation from field data (2014)

The number of publications had a positive correlation with work experience. The results showed that 29% of the respondents had no publication, 26% had between two to five publications and, 18% had between six to ten publications while 28% had more than ten publications.

The government of Ghana (GoG) was the main source of funding for the salaries and emoluments of 77% of researchers interviewed.

Researchers' areas of specialization were also considered. Figure 4.1 shows that 18% of researchers specialized in plant breeding, 16% each in agronomy and agricultural economics and 12% had specialization in extension communication. The least areas of specialization among scientists were irrigation agronomy and water management (2%) and weed science (2%). Research assistants should be encouraged to specialize in these two areas in pursuit of their further studies. This is because farming systems research programmes are holistic in terms of area of specialization and experiences from different research background are required to produce a complete crop management technique or innovation.

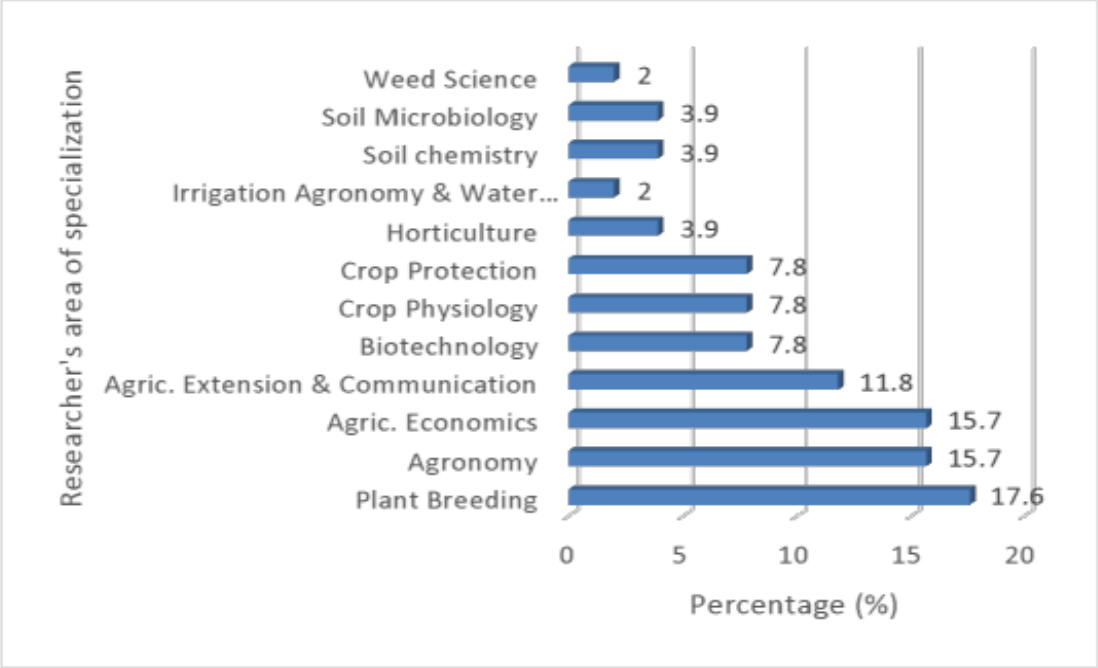


Figure 4.1 Researchers' Areas of Specialization Source:
Computation from field data (2014)

4.2.2 Funding of Agricultural Research

Funding of research as part of donor support to the agricultural sector comes in the form of projects. From the findings, 73% of researchers indicated that the projects they were implementing were donor funded while the remaining 30% indicated that institutional grants and the private sector were the sources of their funding. According to Wolter (2008), the number of donor projects to Sub-Sahara Africa is increasing. From the findings also, 35% of the researchers indicated that funding had increased while 39% said it remained the same within the last five years. However, 26% indicated that funding had declined.

On the decline in funding to agricultural research, 18% of the respondents who said funding had declined within the last five years estimated the decline to be between 5-20%

while the remaining 8% put the decline in funding at between 30-50%. On the percentage of increase in funding to agricultural research, 16% of the respondents who said funding had increased within the last five years estimated the increase to be between 5-20% while the remaining 19% estimated such an increase to be between 30-50%.

Appiah *et al.* (2012) reported inadequate funding to be the most serious limitation to research activities because it affects the provision of infrastructure and general operations and motivation among scientists. The authors in assessing the trend of government subvention released to the Forestry Research Institute (FORIG) of the Council for Scientific and Industrial Research (CSIR) over a ten year period (between 2000 and 2010), realized that the research component constituted only 2% of the total subvention allocated within the ten year period. According to Schacht (2012), one of the success stories about the Bayh-Dole Act of U.S. was the certainty and assurance it conveyed to scientists concerning ownership of intellectual property. It provided universities an incentive to take the pain and effort to pursue a patent and to license those patents. Subsequently, the academia became a major source of innovation for local and regional economic development. Not only does research commercialization rewards researchers for their hard work, it leads to societal good. It was therefore important to assess the level of commercialization among researchers and the benefits accruing to them.

For the past five years, only 21%, as against 79% of the respondents, had sold at least an output from their research or rendered an extension service for a fee. Seed growers, NGOs and farmers were mainly the clientele for such outputs or services. The output sold from research were improved seeds (mainly rice, maize and soya bean), consultancy

services to NGOs and training programmes for farmers, Farmer Based Organizations (FBOs) on good agricultural practices and extension services on safe use of agro-chemicals. Figure 4.2 shows that consultancy service to NGOs was the highest (60%) followed by the sale of improved seed. The least output sold was training programmes for famer based organizations (FBOs). There was no reward for patenting among researchers or commercialization of any form of "restricted" innovation. This is an indication that as at the time of data collection, there was no real commercialization among researchers.

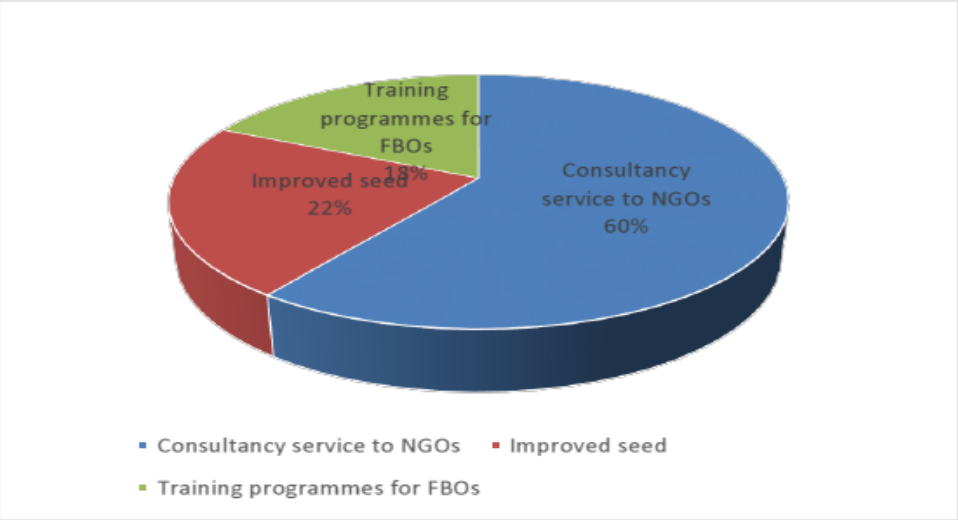


Figure 4.2 Specific research output sold within the last five years by researchers

Source: Computation from field data (2014)

4.2.3 Researchers' Opinion about the Factors Influencing the Commercialization of Research Findings

The opinion of researchers with respect to the factors influencing the commercialization of research findings was sought for in the study. From Table 4.2, while the majority of

respondents (55%) thought that the non-profit (public good) nature of research findings would not affect sales, 45% thought it would. The latter thought that being a public good, there would be a free-rider problem.

The level of collaboration among researchers in the implementation of research projects was assessed. From the table, 22%, 45% and 33% recorded below average, average and above average respectively. The survey results showed that 84% of researchers indicated that collaboration with other researchers could help in selling their research results, since such collaboration would improve the quality of research findings.

Some 59% of respondents believed that one`s source of salary and emoluments had an influence on one's commercialization drive. Thus, a researcher whose salary and emoluments is not dependent on returns from the sale of his research findings, would be less likely enthused about commercialization of such findings.

Similarly, 47% of researchers held the opinion that the necessity to publish in order to gain promotion in the various public Universities and Research Institutions could have a negative influence on the commercialization of research findings. This is because once such findings/ innovations become public (through publications), it then becomes difficult to sell such innovations. However, 57% of respondents thought otherwise.

Table 4.2 Factors influencing commercialization of research findings

	FACTORS	PERCENT (%)
1.	Non-profit nature of research would affect research commercialization	
	YES	45
	NO	55
2.	Your perception regarding the level of collaboration between you and other researchers in the implementation of projects	
	Below Average	22
	Average	45
	Above Average	33
3.	Will your collaboration with other researchers help in the selling of research results	
	Yes	84
	No	16
4.	Will the source of your salary and emoluments affect the commercialization drive of your research findings?	
	YES	77
	NO	23
5.	The necessity to publish for promotion would negatively affect research Commercialization	
	YES	43
	NO	57

Source: Computation from field data (2014)

4.3 Willingness to sell Innovations from Research

The main objective of this study was to assess researchers` willingness to sell innovations from research and farmers' willingness to pay for such innovations. Figure 4.3 shows that 59% of researchers were willing to sell their innovations or provide extension service to farmers for a fee.

Figure 4.3 Researchers' Willingness to sell innovations from research
Source: Computation from field data (2014)

4.3.1 Reasons for Researcher's Willingness to sell Innovations

The respondents who expressed their willingness to sell innovations from research gave various reasons for their answer as indicated in Table 4.3. The highest percentage of respondents (43.3%) considered private participation as critical in sustaining funding for agricultural research. Similarly, 26.7% thought that farmers would value research innovations more if they paid for such innovations. About 16.7% of respondents saw service charges from the sale of innovations as a source of motivation and incentive to researchers, and the remaining 13.3% thought that research commercialization would improve access to research innovations and extension services.

Table 4.3 Reasons for researchers' willingness to sell innovations from research

REASONS	FREQUENCY	PERCENTAGE (%)
1. Sustaining funding for agricultural research by allowing for private participation	13	43.3
1. Farmers will value findings from research/ extension service more if they pay for them	8	26.7
2. An incentive and motivation to researchers	5	16.7
3. Improving access to innovations from research	4	13.3
TOTAL	**30**	**100**

Source: Computation from field data (2014)

4.3.2 Reasons for Researchers' unwillingness to sell Research Innovations

The forty one percent of respondents who said they would not be willing to sell their innovations also gave their reasons as summarized in Table 4.4. The highest percentage of respondents considered low income levels among farmers as a factor that would militate against research commercialization. Similarly, the least percentage of respondents not willing to sell saw research commercialization leading to low adoption of technologies.

Table 4.4 Reasons for researchers' unwillingness to sell innovations from research

REASONS	FREQUENCY	PERCENTAGE (%)
1. Farmers generally have low incomes and cannot afford to pay for innovations/ extension service	10	47.6
2. Commercialization of research findings could lead to low adoption of technologies	5	23.8
3. Low level of education among farmers could hinder farmers willingness to pay for innovations	6	28.6
TOTAL	**21**	**100**

Source: Computation from field data (2014)

4.4 Socio-Economic Characteristics of Farmers

From Table 4.5, 64% of the farmers were male while 36% were female. The Study had more male farmers than female farmers because in Ghana men are mostly considered as heads of households and tend to be the owners of household assets including farmlands.

The mean age of the respondents was 40 years and ranged from 15 to 96 years.

The mean household size was 10 also ranging from 2 and 30. This is above the national household size of 4 people.

Table 4.5 Farmers Socio-Economic Characteristics

CHARACTERISTICS OF RESPONDENTS	FREQUENCY n= 360	PERCENTAGE (%)	STATISTIC
Sex			
Male	229	63.6	
Female	131	36.4	
Age			Mean=40
15-25	38	10.6	Minimum age =15
26-35	124	34.4	Maximum age =96
36-45	102	28.3	Std. Dev.= 13.08
46-55	52	14.4	
56-65	24	6.7	
66 and above	20	5.5	
Household Size			Mean=10 Min.=2 Max.=30 Std. Deviation=5.03
Formal Education			
None	240	66.67	
Basic	49	13.62	
Secondary	51	14.17	
Tertiary	20	5.54	
Farming Experience			Mean=22.67 Min.=2 Max.=70 Std. Deviation=13.95
Farm Size (acres)			Mean=6.69 Min.=0.25 Max.=54 Std. Deviation=5.6
Membership to an FBO			
Belong to FBO	144	40	
Not a member of FBO	216	60	
Nativity			
Yes	299	83	
No	61	17	
Non-Farm Income			GH₵761.00
Farm Income			GH₵962.00
Contact with an A.E.A			
Yes	244	62.2	4
No	136	37.8	

The major source of labour for farming is the household. Its size therefore has a positive influence on available labour for farming.

Majority of the farmers (83%) were natives while the remaining 17% were settler farmers.

Education is generally considered as a prerequisite for development. It enables an individual to make choices independently, and to act on the basis of such choices. It also increases the tendency for someone to cooperate with other people (Enete and Igbokwe, 2009; Ofori, 1973). Figure 4.4 shows that 66% of the farmers had no formal education. The remaining 33% had at least three years formal education.

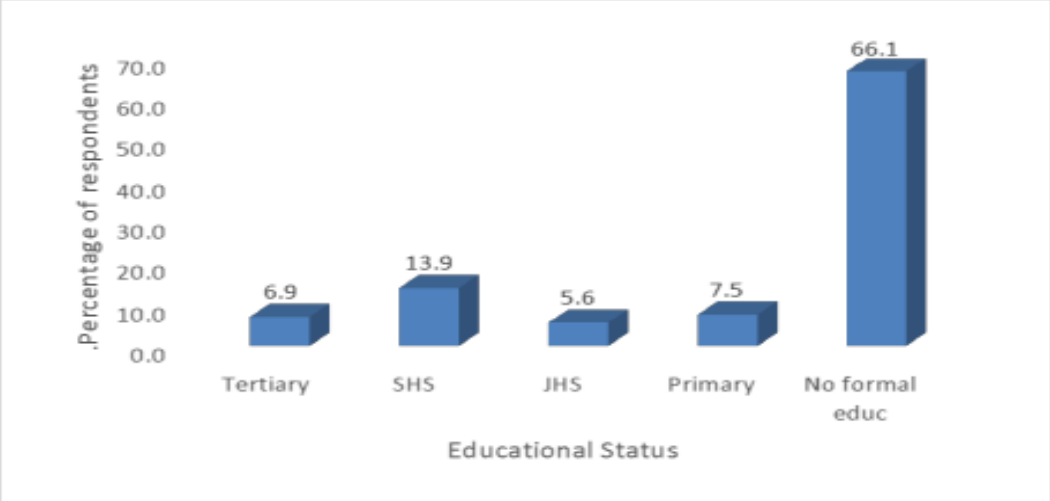


Figure 4.4 Educational status of farmers
Source: Computation from field data (2014)

From table 4.5, the average number of years the respondents spent in farming was 23 years, with the least number of years spent by a farmer being 2 years and the maximum

years being 70 years. However, the most occurring years of experience (mode) was 20 years. Sixty farmers from the total of 360 had spent 20 years in farming and only one farmer had spent 70 years in farming. The number of years a farmer spent in farming (years of experience) correlates positively with his age. This was at 5% significance level. Thus as the farmer ages, he/ she accumulates more experience in his farming activities. Agricultural production in northern Ghana is largely rain fed. An older farmer, *ceteris paribus*, is expected to have more experience than a younger farmer who has lived and cultivated in fewer seasons.

The mean farm size was 7 acres. Figure 4.5 indicates that 50 % of the farmers cultivated 2 to 5 acres during the 2013 cropping season, followed by 29.2 % cultivating 6 to 10 acres. The only few farming households cultivated land area below 1 acre (3.9 %). Also, only few farming households cultivated areas above 21 acres.

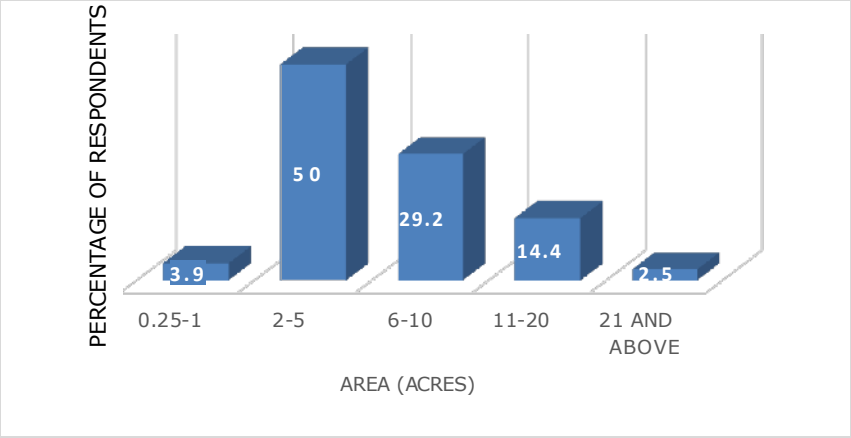


Figure 4.5 Land area under cultivation (in acres) for the 2013 cropping season
Source: Computation from field data (2014)

About 40 % of the farmers belonged to Farmer Based Organizations (FBOs). Farmers who were members of FBOs saw working together as a means of improving their individual livelihoods. Members of FBOs were into activities such as production, bulk input procurement such as weedicides, improved seed and fertilizer, and internal credit schemes, commonly referred to as "susu". Members of FBOs enjoyed mutual labour support from one another, especially for cultural practices such as planting, weeding and harvesting. These findings support that of Salifu *et al.* (2012) that members of an FBO will often have a time table in place so that all members of the group benefit in turns on their individual farms from the mutual labour support. Salifu *et al.* (2012) also found production, procession, marketing, input procurement, welfare services and community development, as some of the collective activities that FBOs in Ghana are engaged in.

About 74% of the farmers had other sources of income. These non-farm income sources included sale of horticultural crops and fruits, milk and eggs, animal sales, fish sales, remittances, salaried work, self-employed activities and casual labor. While the mean non-farm income was GH₵761.00 that of farm income was found to be GH₵962.00

Access to agricultural extension services remains the most important means of improving adoption of innovations from research. For developing countries, extension officers remain the most effective means of delivering agricultural extension services. About 62% of the respondents had access to agricultural extension services while 38% did not. On average, a respondent accessed agricultural extension service from an A.E.A. four times within the year 2013.

The findings revealed that 92% of the farmers were aware of the existence of one agricultural innovation or the other. This was mainly due to agricultural extension programmes run by the various local FM stations, contacts with A.E.As and NGOs over the years as well as through field demonstrations. Figure 4.6 shows that over the past 3 years, 45% of the respondents became aware of research innovations through the local FM stations, 30% through contact with agricultural extension agents, 10% through contacts with NGOs and 7% through field demonstrations. With this high level of awareness, we can go ahead to investigate farmers' willingness to pay for research innovations. This is because according to Desvousges *et al.* (1993) respondents' familiarity with a good or service is a necessary prerequisite to providing meaningful responses to CV questions.

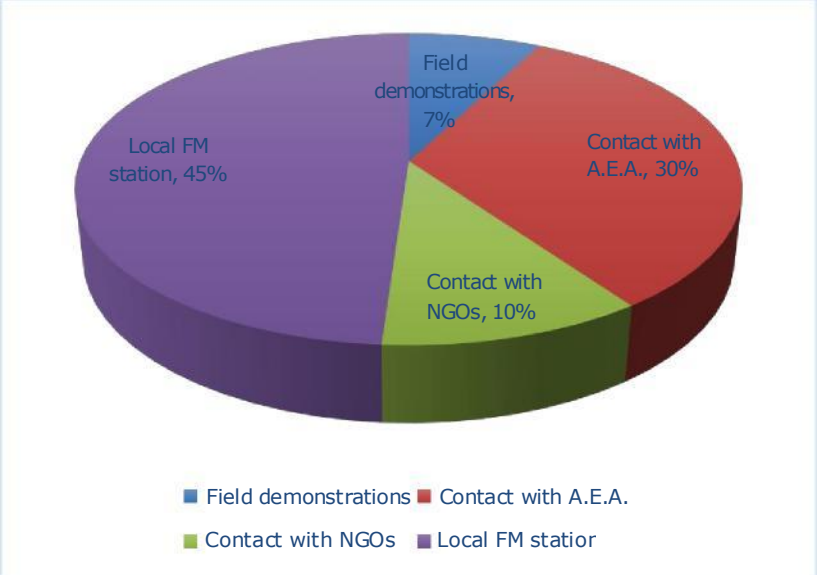


Figure 4.6 Media through which farmers became aware of innovations
Source: Computation from field data (2014)

4.5 Valuation of Technologies and Farmers' Free-ride

The specific objectives one and two of the study were to assess how much researchers and farmers were willing to sell and pay for a given technology. The rationale behind a WTP study is that it indicates the value that individuals attach to a good or service, which in turn predicts their likely contribution towards the maintenance of the said good or service (Boadu, 1993). Willingness to accept payment (willingness to sell) represents a compensation for the loss of a good or service. In this study, a researcher's willingness to accept payment represents the opportunity cost of extending a research innovation to a farmer.

Table 4.6 indicates the amounts researchers were willing to accept as payment for their innovations. For payments below the minimum stated values, researchers were not willing to sell their innovations. On the other hand, currently, researchers would also not charge farmers above the stated maximum value for a given innovation. Extending innovations to farmers on record keeping and farm management was the least valued by researchers while that of soil fertility management had the highest value. Researchers were willing to accept GH₵43.00 and GH₵57.00, per farmer to provide a day`s training on record keeping and farm management techniques as well as soil fertility management techniques, respectively. Below these stated amounts researchers were not willing to sell these techniques. Similarly, researchers would also not be charging more than GH₵85.00 and GH₵100.00 per farmer for these two innovations.

The willingness to accept offers from researchers is important in two ways. One, it shows the amount of money that will be required to ensure the future flow of each of the

research innovations to farmers. For example, for a farmer to obtain one additional unit of an innovation on soil fertility management, a researcher is willing to charge at least GH₵57.00 per farmer per day. As far as the researcher is concerned, this stated amount will maintain the future provision of the innovation. This leads to the second important point that the WTA offers have quantified the economic values associated with the provision of the given research innovations. The WTA offers in this study are significantly not different from the findings of Kolavalli *et al.* (2010) that the costs of extension service provided per farmer for the year 2006 were GH₵52.00 for the Brong-Ahafo region, GH₵64.00 for Northern region and GH₵93.00 for the Western region.

Table 4.6 Researchers' WTA offers

TECHNOLOGIES	PRICES OFFERED (GH₵)	
	Minimum WTA	Maximum WTA
1. Soil fertility management techniques	57.00	100.00
2. Weeds and Insect Pest control methods	53.00	100.00
3. Knowledge on safe-use of agro-chemicals	53.00	100.00
4. Post-harvest techniques	50.00	100.00
5. Crop Disease Identification and Control Methods	44.00	96.00
6. Record keeping and farm management techniques	43.00	85.00

Source: Computation from field data (2014)

4.5.1 Seed System and Farmers' WTP for Improved Seed

Farmers usually obtain seeds for planting from the following sources: own farm, neighbors, relatives, farmer groups, research institutions, seed growers, NGO, MoFA and agro input shops. In this study, 84 % of farmers used their own seeds for planting, as shown in figure 4.7. Thus they stored some of the seeds from harvest and planted it during the next season. This supports the finding of Tripp and Mensah-Bonsu (2013) that there is widespread and national practice of seed saving among farmers in Ghana. They contended however that this practice is not necessarily a barrier to improved seed industry development, as long as there is a relatively constant annual demand from farmers who wish to change varieties or to occasionally renew their seed for the same variety.

The next common source of seeding for farmers was agro-input shops in the markets (6.9%). The least source where farmers obtained seeds was from research stations (1.1%). This is mainly because currently, research institutions do not serve as commercialization centres for improved seed.

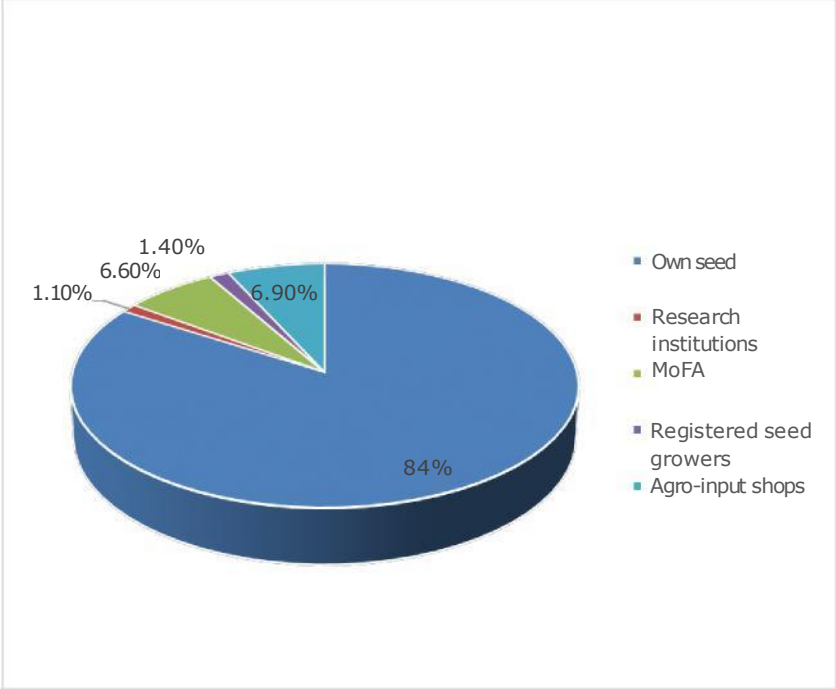


Figure 4.7 Farmers' source of seed for the 2013 cropping season
Source: Computation from field data (2014)

Table 4.7 shows that the farmers were willing to pay between GH₵2.00 and GH₵4.00 for improved seeds of maize, rice and soya bean. At prices above GH₵4.00, farmers were not willing to pay for improved seed. Efforts at promoting the use of hybrid seeds among farmers might not be successful currently. This is because the price of hybrid seed, for example, maize (Panar 53) was GH₵10.00 per 1Kg, far above the maximum stated WTP by the farmers. Efforts should rather be geared towards improving access to the Open Pollinated Varieties (OPVs) whose prices, as indicated in figure 4.9 are within the farmers' stated willingness to pay values. Prices of the OPVs ranged from GH₵1.77 to GH₵2.66 for maize, rice, soya bean and sorghum for the 2014 cropping season (SEEDPAG, 2014).

Table 4.7 Farmers' WTP for improved seed of some selected crops

CROP	PRICES OFFERED FOR 1Kg	
	Minimum (GH₵)	Maximum (GH₵)
Maize	2.00	4.00
Rice	2.00	3.00
Soya bean	3.00	4.00
Sorghum	1.00	3.00
Tomatoes	3.00	4.00

Source: Computation from field data (2014)

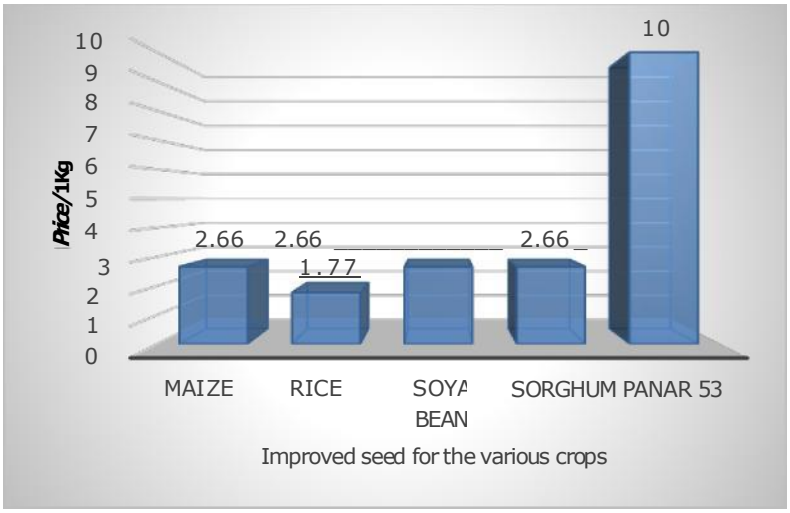


Figure 4.8 Prices for improved seeds for 2014

Source: SEEDPAG, Northern Region (2014)

4.5.2 Farmers' Willingness to Pay for other Improved Farming Technologies

Farmers' willingness to pay for soil fertility management techniques, field crop protection techniques, safe-use of agro-chemicals, post-harvest techniques and farm management and record keeping techniques were also valued. It is important to note that different types of crop technologies have both hardware and software components. An improved crop variety, as a type of hardware technology, cannot be fully exploited without having a complementary set of agronomic practices (FAO, 1997), hence assessing farmers' WTP for these technologies as well as the valuation of these technologies. Table 4.8 shows the values farmers offered for these technologies.

4.5.2.1 Soil Fertility Management

About 89% of the respondents applied fertilizer on their fields. The fertilizer subsidy programme might have accounted for the high percentage use of fertilizer among respondents for the 2013 cropping season. About 48% of the farmers had received training on ways or methods of improving soil fertility for increased yield as against 52% who did not receive any training. Majority of the respondents (91%) said they were willing to pay to receive training on methods of improving soil fertility. Farmers were willing to pay as low as GH₵4.00 each for a day's training and as high as GH₵6.00. They were not willing to pay for a day's training on soil fertility management above GH₵6.00.

Table 4.8 Farmers' WTP values for the various technologies

TECHNOLOGIES	% OF FARMERS' WTP FOR TECHNOLOGIES	WTP OFFERS	
		MINIMUM PRICE (GH₵)	MAXIMUM PRICE (GH₵)
1. Soil fertility management technologies	91	4.00	6.00
2. Weeds and field pest control techniques	94	4.00	6.00
3. Techniques on safe-use of agro-chemicals	94	4.00	6.00
4. Identification and control of field crop diseases	93	4.00	6.00
5. Post-harvest technologies	91	3.00	6.00
6. Farm Management & Record Keeping	29	4.00	6.00

Source: Computation from field data (2014)

4.5.2.2 Crop Protection

All the respondents, except one, were aware that insect pest and weeds reduce both the quality and quantity of crop yield. About 51% had training on methods of field insect pest control. Nonetheless 49% of the respondents said they never had the opportunity of such training. On WTP, 94% were willing to pay to receive training on ways or methods of controlling weeds and pest on their fields. Respondents were willing to pay as low as GH₵4.00 and as high as GH₵6.00 to receive training on ways of controlling weeds and insect pest on crop fields. Thus above GH₵6.00, respondents were not willing to pay to receive such training.

About 95% were aware that the use of agro-chemicals (weedicides and insecticides) could be harmful to one's health and the environment. Majority of the farmers (94%) were willing to pay to receive training on safe use of agro-chemicals. Those willing to pay to receive training on safe use of agro-chemicals were prepared to pay as low as GH₵4.00 and as high as high as GH₵6.00, on average to receive the training. Some 51 % of respondents said they did not use protective clothing when spraying their fields with agro-chemicals. On knowledge on preventing field crop diseases, 93% said they were willing to pay and were prepared to pay a minimum of GH₵4.00 and a maximum of GH₵6.00.

4.5.2.3 Post-Harvest Techniques

Post-harvest losses is reported to be very high in Ghana. Post-harvest losses are about 20%-50% for fruits, vegetables, roots and tubers, and about 20%-30% for cereals and legumes (MoFA, 2007). Almost all the respondents (97%) reported incidence of insect pest infestation during storage of farm produce. From the findings, 91% were willing to pay to receive training on post-harvest techniques in order to increase the shelf life of their farm produce during storage. These farmers were willing to pay a minimum of GH₵3.00 and a maximum of GH₵6.00. Above GH₵6.00, respondents were not willing to pay for post-harvest techniques.

4.5.2.4 Farm Management and Record Keeping Techniques

Farmers are encouraged to see farming as business rather than as a way of life. Thus farmers should keep simple production records on their farm business and also have some level of skills to manage the farm as a business. There was low record keeping among famers, as 71% did not keep records of their farming activities.

However 29% of farmers were willing to pay to receive training on records keeping to improve their farm management skills. They were ready to pay a minimum of GH₵4.00 and a maximum of GH₵6.00 to receive a day's training. About 71% of the farmers however, were not willing to pay to receive training on records keeping and farm management.

4.5.3 Farmers' Level of Free-riding

Free-riding was investigated at two stages in the administration of the questionnaire. The first stage consisted of finding out from respondents who expressed willingness to pay for a technology, whether they were also willing to share the knowledge with other farmers for free. Likewise, respondents who were not willing to pay for a particular technology were also asked whether they were willing to access paid-for technologies from friends for free. The essence of this was to determine the presence or otherwise of free-riding among respondents in the face of research commercialization of technologies. The final stage of measuring free-ride was to use it as a variable for empirically testing its effect on farmers' WTP. At this stage farmers again were asked whether they were still willing to pay for the proposed package of research technologies if such technologies were available to them for free from family members and friends. This repetition of

questioning on free-riding was necessary because according to Hoyos and Mariel (2010), efficiency in the responses to questions can be increased if repeated questions are used. There was presence of free-riding for all the "soft-ware" technologies valued.

About 78% of the respondents who said they were willing to pay for training on soil fertility management indicated that they were also willing to share the knowledge obtained from the training for free with friends who could not afford the cost of the training. About 80% of respondents were willing to share the knowledge they paid for on controlling weeds and insect pest on crop fields with friends for free. . Lastly, 81% of the farmers were willing to share their knowledge with friends for free on post-harvest techniques though they might have paid for it.

A proportion of 78.3 % of respondents, who said they were not willing to pay for training on soil fertility management were however willing to access such knowledge from friends for free. Also 76.4% of respondents will like to access knowledge from friends for free if they were not able to pay for training on ways of controlling weeds and insect pest.

About 71% of the respondents not willing to pay to receive training on safe use of agro-chemicals were ready to access such knowledge from friends for free.

4.5.4 Comparison of Farmers' Maximum WTP and Researchers' Minimum WTA

The study has revealed a very wide divergence between farmers' maximum willingness to pay for agricultural innovations and researchers' minimum willingness to accept payment for their innovations. The cause of the divergence was as a result of farmers and

researchers belonging to two diverging income groups. Researchers are wealthier than the farmers and so WTA will substantially differ from WTP (Hoffman and Spitzer, 1993). The study revealed that on average, the basic monthly salary for a researcher with first degree was GH₵1440.00 and that of a non-PhD was GHC1750.00. PhD researchers had a mean basic monthly salary of GHC2380.00. This is in sharp contrast to farmers' mean farm income of GH₵968.00.

From the study, farmers would not pay for innovations at amounts higher than their stated maximum WTP, and researchers would not sell their innovations at prices lower than their minimum WTA. This is a sticky situation, according to Hoffman and Spitzer (1993) and no commercialization of research innovations could take place because farmers would not be able to offer enough money to obtain innovations from researchers. It is therefore very essential to overcome this sticky situation if commercialization of innovations must take place. Research commercialization is driven by the motivation of improving the quality of research innovations and making them accessible to farmers. It also aims at ensuring sustainable funding for research and subsequently for continuous generation of innovations.

The imperativeness of sustainable funding for research cannot be overemphasized. This is because inefficiencies may reduce the quality or even bring to an end the provision of services such as agricultural research and extension. Experiences across the globe have shown that inefficiencies are unavoidable if a service such as extension is provided free of charge to end-users (Ali *et al.* 2008). However the valuation from the farmers is a reflection of what they were willing to trade off to improve and maintain the provision of

innovations from research, in order to have the benefit of higher crop yields, hence higher incomes. For example for a farmer to obtain one additional unit of any of the innovations, he/ she was willing to give up at most GH₵6.00. This, on average, only constitutes 12.15% of researchers' minimum WTA for any given innovation. It is therefore unlikely that farmers' annual willingness to pay for innovations from research will even cover 13% of the estimated annual costs, at least in the short term. This finding suggests that research commercialization is an area where subsidies will be required if it is to be successful. The subsidy could be in the form of continues government subvention to research institutions.

Table 4.9 Comparison of farmers maximum WTP and researchers minimum WTA

TECHNOLOGIES	FARMERS' MAXIMUM WTP	RESEARCHERS' MINIMUM WTA	RATIOS OF WTP TO WTA	RATIOS IN PERCENTAGES (Mean= 12.15%)
1. Soil fertility management technologies	6	57.00	1: 9.5	10.526
2. Weeds and field pest control techniques	6	53.00	1: 8.8	11.364
3. Techniques on safe-use of agro-chemicals	6	53.00	1: 8.8	11.364
4. Identification and control of field crop diseases	6	50.00	1: 8.3	12.048
5. Post-harvest technologies	6	44.00	1: 7.3	13.699
6. Farm Management & Record Keeping	6	43.00	1: 7.2	13.88

Source: Computation from field data (2014)

4.6 Estimation of Probit and Multivariate Probit Models

4.6.1 Definition of Variables

There were two sets of variables used for estimation in this study. The first set are researchers' socio-economic variables believed to be affecting their decision to accept payment for innovations from research, as shown in Table 4.10. These variables include age, membership to a professional body, years of experience as researchers, researchers' perception regarding technology transfer as profitable or otherwise, dependence on stated source of salary and the necessity on researchers to have a certain number of publications before they could be promoted. Table 4.11 outlines the second set of variables (farmers' socio-economic variables) influencing farmers' willingness to pay for innovations from research. These variables are farmers' age, educational status, whether a farmer was a native or settler, whether or not a farmer was a potential free-rider, size of a farmer's farm, farm income and off-farm income from the previous year and the number of contacts with an agricultural extension agent.

Table 4.10 Definition of Researchers' Socio-economic variables

Variable	Definition and Measurement	*A Priori* Expectation
WTA (**dependent variable**)	Researcher's WTA payment for his innovations (Dummy;1if yes; 0 otherwise)	Positive/ Negative
Explanatory variables:		
Age of respondent	Age of a researcher, measured in years.	Positive
Membership to a professional body	Dummy; 1 if a researcher belonged to a professional body; 0 otherwise	Positive
Years of Experience	Number of years a respondent had been a researcher.	Positive
Number of publications	Number of research published papers a respondent had	Positive
Researchers' perception regarding the non-profit nature of extension delivery (technology transfer)	Dummy; 1 if a researcher perceived that the non-profit nature of extension delivery negatively affected research commercialization; 0 otherwise	Negative
Dependence on stated regular source of salary (Government subvention)	Dummy; 1 if regular source of salary will affect commercialization positively; 0 otherwise	Negative
Necessity to publish in order to be promoted	Dummy; 1 if a researcher agreed that the necessity to publish in order to be promoted could increase research commercialization; 0 otherwise	Positive/ Negative

Table 4.11 Definition of Farmers' socio-economic variables

Variable	Definition and Measurement	*A Priori* Expectation
WTP (**dependent variable**)	Dummy; 1 if a respondent was willing to pay for a research technology; 0 otherwise	Positive/ Negative
Explanatory variables:		
Age	How old a respondent was, measured in years	Positive
Educational Status	Dummy; 1 if a respondent had formal education; 0 otherwise	Positive
Farm Income	Value of total produce sold for the 2013 cropping season, in Ghana Cedis (GH₵)	positive
Non-Farm Income	Total income received from non-farm sources, e.g. trading, remittances, etc., in Ghana Cedis (GH₵)	Positive
Nativity	Dummy; 1 if the respondent was a native of the community; 0 if settler farmer	Positive
Free-rider	Dummy; 1 if a farmer who could obtain improved seed and knowledge on agricultural technologies free of charge from friends and relatives was also willing to pay; 0 if a farmer would not pay for innovations because he could free-ride	Negative
Number of acres	Total area of land under cultivation owned by a respondent, in acres.	Positive
Number of contacts with an A.E.A.	Number of times within the 2013 cropping season a respondent interacted with an A.E.A. on agricultural services	Positive

4.6.2 Determinants of Researchers' Willingness to sell Innovations

Objective 3 of the study sought to examine the factors that influenced researchers` willingness to sell the following technologies: improved seed varieties, soil fertility improvement techniques, weed and pest control methods, safe use of agro-chemicals, field crop disease control, post-harvest techniques as well as farm management and record keeping. The probit model was used.

The age of researchers had a significant negative influence on willingness to sell research innovations. Table 4.12 indicates that an increase in age of a researcher by one year will result in a decrease of the probability of the researcher willing to sell his innovations by 2%. Possibly, because this study is ex ante, older researchers might have assumed that they would not be in active service during a policy of commercialization of research technologies, hence their unwillingness to sell research innovations. Similarly, younger researchers are more commercially oriented because they need to earn more money, besides their salaries in order to have a good start in life.

A researcher`s membership to a professional body had a positive influence on his/ her willingness to sell his/ her research technologies. Thus, researchers who belonged to professional bodies were more willing to commercialize innovations from research than those who did not belong to any professional body. Membership to a professional body increases one`s network, business orientation and social capital. The positive influence of membership to a professional body on their willingness to commercialize innovations from research was significant at 5%. It is expected that researchers who become members of professional bodies will lead to a higher probability of willingness to sell innovations

by 44%. The number of publications by a researcher also had a positive influence on the willingness to commercialize. Thus, as the number of publications by a researcher increases, his willingness to sell research technologies also increases. This was significant at 5%. Furthermore, an increase in the number of publications by one will increase the probability of a researcher willing to sell innovations by 8%.

Table 4.12 Marginal effects of the factors influencing researchers' willingness to sell research innovations

EXPLANATORY VARIABLES	MARGINAL EFFECTS	STD. ERROR
Age	-0.0184289	0.00766**
Membership to a professional body	0.4425909	0.17524**
Respondents` years of experience	0.0155304	0.03222
Number of publications of a researcher	0.0669063	0.03023**
Non-profit nature of extension delivery	-0.2900798	0.19142
Dependence on stated source of salary	0.1435752	0.18466
Necessity to publish in order to be promoted	0.0788004	0.17491

** represent significance level of 5%

Source: Computation based on probit from field data (2014)

4.6.3 Determinants of Farmers' WTP for Research Innovations

Objective 4 of the study sought to examine the factors that influenced farmers' willingness to pay for improved technologies. This is against the backdrop of growing interest in the participation of the private sector in funding agricultural research. Most of the time, financial contributions from one of the end-users of innovations from agricultural research is overlooked, as emphasis is often placed on small, medium and large scale agri-enterprises. Donkoh and Awuni (2011) noting the inadequacy and poor remuneration and motivation among agricultural extension staff in Ghana, like in many other developing economies, suggested the privatization of extension delivery. Their concern was however whether farmers will be able to pay for the services against the backdrop that over 92% of them are small scale farmers (MoFA, 2007).

The estimation from the Multivariate Probit model (MVProbit) looked at farmers` willingness to pay for the following technologies: improved seed varieties, soil fertility improvement techniques, weed and pest control methods, safe use of agro-chemicals, field crop diseases control, post-harvest techniques and farm management and record keeping.

The log likelihood and Wald chi-square values were -550 and 143.44 respectively. The Wald chi-square value was significant at 1%, suggesting that all the explanatory variables jointly determined the dependent variable. The endogeneity within the data set, as evidenced by the positive correlations between willingness to pay for the various technologies was corrected using Geweke-Hajivassiliou-Kean (GHK) smooth recursive conditioning simulator. According to Ulimwengu and Sanyal, 2011; and Kankwamba *et*

al. 2012, such endogeneity could be corrected using GHK smooth recursive conditioning simulator, a simulation method for evaluating multivariate normal distribution functions (Keane, 1994; Borsch-Supan and Hajivassiliou, 1993).

Table 4.13 MV Probit indicating factors influencing farmers' WTP for Innovations

Explanatory Variables	Improved Seed	Soil Fertility Improvement techniques	Weeds and Insect Pest control methods	Safe use of agro-chemicals	Farm Management and Record Keeping	Post-Harvest Techniques
	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Age	-0.0222541 (0.0083612)***	-0.0285107 (0.0081633)***	-0.0294915 (0.0092794)***	-0.0487716 (0.0100546)***	-0.0061457 (0.0060389)	-0.0213486 (0.0076276)***
Educational Status	0.8566023 (0.4063613) **	-0.0004373 (0.2269114)	-0.0898358 (0.2734372)	-0.4790022 (0.2654224)*	0.430929 (0.1556653)***	-0.144377 (0.2155912)
Nativity	0.8973799 (0.2481937)***	0.7725424 (0.2414772)**	0.8741929 (0.2820333)***	0.2542582 (0.313295)	-0.0029226 (0.2138322)	0.0818802 (0.2621454)
Free-Rider	0.4872093 (0.2353743)**	0.4128067 (0.2207351)*	0.4746116 (0.2559607)*	0.4662275 (0.2736648)	0.3498178 (0.1878753)*	0.5004964 (0.2112851)**
Number of Acres	0.0130904 (0.0227986)	0.0121588 (0.020583)	0.0471642 (0.0303452)	0.0633813 (0.0348181)*	-0.081843 (0.0134122)	0.0048097 (0.0175745)
Off-Farm Income	0.0130904 (0.0001053)	-0.0001431 (0.0000467)***	-0.0001078 (0.000062)*	9.89e-07 (0.0000751)	-0.000032 (0.0000453)	-0.0000106 (0.0000543)
Farm Income	0.0001169 (0.0001506)	0.0000733 (0.0000963)	0.0005268 (0.0002579)**	0.0005268 (0.0002799)*	0.0000625 (0.0000699)	-0.000062 (0.0000686)
Number of contact with an A.E.A.	0.0552829 (0.32997)*	-0.0308932 (0.0245868)	-0.047721 (0.0259496)*	-0.0610719 (0.0257548)**	0.0867617 (0.0174427)***	0.0043998 (0.0253028)

*,**, ***, represent 10%, 5% and 1% levels of significance respectively.

NB. Std. Errors are in Parenthesis.

Source: MV Probit results from computation based on field data (2014)

Across all the technologies, age of the respondents had a significant negative influence on their willingness to pay for agricultural technologies. This means that as farmers grow older, the probability of their willingness to pay for agricultural innovations decreases. This possibly could be because older people will not like to go through the mental stress associated with learning agricultural technologies and may also be risk averse. This finding is consistent with that of Mwaura *et al.* (2010) and Kaliba *et al.* (1997). Mwaura *et al.* (2010) found that increasing age of respondents was associated with reducing likelihood for their willingness to pay for agricultural innovations. To Kaliba *et al.* (1997), young people have relatively high disposable income, are less risk averse, exposed to a wide range of information channels and have the potential to be educated the more.

Except for farmers` willingness to pay for crop diseases control and farm management and record keeping, the age variable was significant at 1% significance level for WTP for the other techniques. From table 4.13, for every additional year above the mean, the probability to pay for improved seed, soil fertility improvement techniques, weed and pest control methods, safe-use of agro-chemicals and post-harvest techniques decreases by 0.022541, 0.285107, 0.094915, 0.0487716 and 0.0213486, respectively, holding all other variables constant.

The educational status of the farmer significantly and positively influenced his/ her WTP for improved seed and knowledge on farm management and record keeping at significance levels of 5% and 1% respectively. Educational status was however found to have a negative influence on farmers` WTP for safe-use of agro-chemicals techniques at

significance level of 10%. Thus farmers who had at least basic education were less willing to pay for training on safe use of agro-chemicals. Farmers with formal education felt they could on their own understand issues regarding safe use of agro-chemicals and did not have to pay to receive additional information.

Nativity significantly and positively affected farmers' WTP for improved seed, soil fertility improvement techniques as well as field crop protection techniques. The nativity variable was significant at 1% for farmers' WTP for improved seed, soil fertility improvement techniques and field crop protection techniques. Thus farmers who were natives were more willing to pay for these innovations as against settler farmers.

The issue of free-rider is often considered as one of the possible limitations to commercializing innovations from agricultural research. According to Sandler (1992), free-riding relates to the inverse relationship between people's contribution towards the maintenance of a public good and non-contributors. The non-contributors still enjoy the public good just as those contributing for its maintenance. Free-riding also relates to the failure of individuals to reveal their true preferences for a public good through their contributions. It presents also the tendency for marginal and average contributions to decline with increasing number of users of a public good or service.

In ascertaining the influence of free-riding on willingness to pay, respondents were asked whether they were still willing to pay for the proposed package of research technologies should they have free access to the same package from family members and friends. From the estimation, the free-ride variable had significant and a positive influence on farmers` WTP for improved seed, soil fertility improvement techniques, field crop

protection, post-harvest techniques, farm management and record keeping techniques as well as techniques on safe use of agro-chemicals. This implies that issue of free-ride exists in the provision of agricultural services, just as any public goods, but contrary to our *a priori* expectations it will increase farmers` WTP for agricultural innovations. The free-ride variable was significant at significance levels of 5% for WTP for improved seed and post-harvest techniques, and 10% for WTP for soil fertility improvement techniques, weed and pest control methods and knowledge on safe use of agro-chemicals. For example, from table 4.13, a farmer who had free advice from a friend on post-harvest techniques, his probability of willing to pay for innovations on post-harvest technology in future will increase by 0.50 or 50%.

The number of acres a farmer cultivated for the 2013 cropping season had no significant influence on WTP for all the technologies, except for safe use of agro-chemicals. Thus, farmers who had more area of land under cultivation were more willing to pay for training on safe use of agro-chemicals. This was at 10% significance level.

The previous off-farm income was found to have a negative influence on farmers` WTP for soil fertility improvement techniques at 1% significance level. The previous off-farm income also significantly and negatively affected farmers' WTP for field crop protection techniques. The previous farm income had a significant and positive effect on farmers' willingness to pay for weeds and pest control techniques as well as safe-use of agro-chemicals.

It was also important to determine whether the number of contacts (field visits) a respondent had with an Agricultural Extension Agent (A.E.A.) had an influence on the

respondent`s willingness to pay for the technologies. This is because according to Donkoh and Awuni (2011), farmers` frequent contacts with extension staff give the farmer the opportunity to learn about the availability and use of innovations from research. The number of contacts (field visits) a respondent had with an extension agent within a year was found to have a positive influence on the respondent`s WTP for farm management and record keeping techniques and improved seed. There were significance levels of 1% for farm management and record keeping and 10% for improved seed. However, farmers who had more visits from agric. extension agents were found to be less willing to pay for weed and pest control methods and safe use of agro-chemicals at significance levels of 10% and 5% respectively. If the number of contacts a farmer had with an extension agent can be used as proxy for measuring prior access to agricultural services, then this finding supports that of Ulimwengu and Sanyal (2011) whose results suggest that prior access to agricultural services tends to reduce farmers` willingness to pay.

The effects of the explanatory variables on farmers' WTP for innovations on crop diseases identification and control measures were not significant, hence not shown in Table 4.13. This is however shown in appendix 4.

Appendix 1 shows the correlation coefficients of willingness to pay for the various technologies.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Introduction

In this chapter, the summary and conclusions of the study are presented in sections 5.2 and 5.3 respectively. The chapter also presents policy recommendations and suggestions for future research.

5.2 Summary

Before the full implementation of the policies and laws aimed at creating the enabling environment for research commercialization, it is important to conduct an ex-ante study to assess whether researchers would be willing to sell their innovations, and more importantly, whether there would be available market or demand for both "hardware" and "software" agricultural technologies, hence this study.

The specific objectives of the study were to determine how much researchers would be willing to sell innovative technologies to farmers in the following areas: improved seed varieties, soil fertility management, weed and insect pest control methods, farm management and record keeping, post-harvest techniques and safe-use of agro-chemicals. Other specific objectives included what factors affect researchers' willingness to accept payment for these technologies, how much would farmers be willing to pay for these technologies and what factors might influence farmers' WTP.

Age of researchers was found to have a significant and negative influence on their willingness to sell research innovations. A researcher's membership to a professional body had a significant and positive influence on willingness to sell innovations. Thus researchers who belonged to professional bodies were found to be more willing to sell their innovations. The number of publications of a researcher had a significant and positive influence on his/ her willingness to sell innovations from research.

There is presently a minimal sale of research technologies in the form of foundation seeds, consultancy service to NGOs and training programmes for FBOs on good agronomic practices. A significant number of researchers interviewed were willing to sell their innovations. Researchers considered commercialization of research innovations as a means of sustaining funding to agricultural research, improving access to innovations from research, motivation for researchers and taking ownership of innovations by end users (farmers). None of the researchers was found to have a patent of any innovation. This means that entrepreneurship is still lacking among researchers.

Similarly, older farmers were found to be less willing to pay for innovations. The educational status of a farmer had a positive influence on willingness to pay for improved seed and accessing knowledge on farm management and record keeping. Native farmers were found to be more willing to pay for most research innovations than settler farmers.

Free-riding will exist in the commercialization of research innovations and will ultimately increase farmers' willingness to pay for innovations. Farmers with large land area under cultivation were more willing to pay for all the technologies except for farm management and record keeping. Frequent contacts with an agric. extension agent within

a cropping season was found to increase farmers' willingness to pay for farm management and record keeping techniques, improved seed and post-harvest techniques. Extension contacts however had a significant and negative influence on farmers' WTP for weeds and pest control methods as well as techniques on safe-use of agro-chemicals.

Previous farm income had a significant and positive effect on WTP for weeds and pest control techniques as well as safe-use of agro-chemicals.

Though a number of farmers were willing to pay for agricultural technologies, it was far less than amounts at which researchers were willing to sell their innovations. Farmers were only able to pay, on average, 12.15% of researchers' minimum WTA for the given innovations. This finding suggests that research commercialization is an area where subsidies will be required if it is to be successful.

There were positive correlations between farmers' willingness to pay for the agricultural technologies. This means that farmers' willingness to pay for one agricultural technology has a positive relationship with their willingness to pay for other agricultural technologies.

5.3 Conclusion

Generally, farmers were willing to pay for innovations from research in the same way that a number of researchers were willing to sell their innovations.

Farmers in the study attached the same value to all the technologies proposed to them. On the whole, farmers were willing to pay a mean of GH₵6.00 for the technologies. This means that farmers give equal importance to research innovations irrespective of whether it is a post-harvest technique or soil fertility management technique.

Among the researchers, there were different valuations for the technologies. Soil fertility management technologies had the highest mean minimum WTA (GH₵57.00) and farm management and record keeping techniques was least valued (GH₵43.00).

Research commercialization would improve quality of research output, access to innovations and motivation to researchers in terms of patents and other service fees. Researchers expressed concern that patent rights might take a longer time to acquire.

The success of research commercialization will be dependent on improvement in both farm and non-farm incomes, increase in land area under cultivation and improvement in the educational status of farmers. Also, on the part of researchers, increase in the number of publications of researchers, encouraging the youth in academia to go into research and scientists becoming members of professional bodies would also enhance research commercialization.

Research commercialization is possible but cannot be an alternative to public funding of research judging from the low WTP valuations from farmers.

5.4 Policy Recommendations

Government can go ahead and implement the policy on research commercialization with two expectations; one, that the monetary returns would be low; and two that at least, research commercialization would serve as another source of revenue for further research.

The wide disparity between WTP and WTA means that commercialization of research could not be run on full cost-recovery. Government should therefore set up a statutory fund dedicated to agricultural research. Government's subvention to research institutions should also be continued during research commercialization. This will serve as subsidy for research commercialization

Researchers should consider the issue of patenting their innovations very seriously, as it is one of the means through which they could get financial reward for their hard work and would be seen as being entrepreneurial.

Researchers should develop entrepreneurial and marketing skills. This is key to reducing the gap between WTA and WTP. Researchers should be encouraged to form and belong to professional bodies as it had a significant and positive influence on willingness to sell innovations from research. Research institutions should continue to use the number of publications of a researcher as requirement for promotions. These institutions could also consider whether a researcher has a patent right as additional requirement for promotions.

Government and research institutions should put in a policy to attract young people into agricultural research.

Policy makers should take keen interest in improving both farm income and non-farm income of farmers. Farm income of farmers could be improved through timely access and adoption of research technologies, improved storage facilities and a better road network between farming communities and market centres.

Based on the findings that older farmers will be less willing to pay for innovations from research, the Ministry of Food and Agriculture and the District Assemblies should implement existing policies aimed at encouraging the youth to go into agriculture.

Also government and non-governmental organizations should employ more agricultural extension agents, as farmers' contact with A.E.As has a positive influence on farmers' WTP. Measures should therefore be put in place to ensure that agricultural extension agents engaged truly work.

Educated people should also be encouraged to go into agriculture. The educational status of less educated people should also be improved through adult-literacy programmes, popularly referred to as "adult education'. This is because improvement in the educational status of farmers will positively influence willingness to pay for most research innovations.

Research innovations could be delivered to farmers as a complete package since their willingness to pay for one innovation has a positive relationship with their willingness to pay for another. Group meetings would be more preferable to personal visits.

5.5 Suggestions for Future Research

The focus of this study was the three regions of northern Ghana. A similar study could be conducted in the southern part of Ghana.

This study considered only farmers. A similar study could look at WTP for innovations from research by SMEs and other actors within the agricultural value chain.

Future work should consider a multivariate tobit to make use of the amounts researchers were willing to accept and farmers were willing to pay. This is believed to give better results than a binary model.

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SAMPLE QUESTIONNAIRES

RESEARCHER LEVEL QUESTIONNAIRE

TOPIC: COMMERCIALIZING INNOVATIONS FROM AGRICULTURAL RESEARCH IN NORTHERN GHANA AND FARMERS' WILLINGNESS TO PAY

HYPOTHETICAL SCENARIO

There is a policy intention to provide research and extension services to farmers **at their own request and convenience.** Under such a policy regime, research and extension services will be provided to farmers at **realistic charges (fees).**

Prior to the implementation of such a policy, we would like to assess your willingness to sell innovations emanating from your research activities, and the provision of training to farmers for a **fee**.

For the purpose of this Study, we would like to assume that you as a researcher are faced with the following problems: inadequate funding for your research activities, and the source of funding being unsustainable in the long run.

Under the new policy, you would be required to sell the output from your research in order to have the **benefit of adequate and sustainable source of funding for your research activities.** The expected outputs from your research are grouped in to packages and each package consists of a number of techniques. **It is assumed that your expertise covers at least one of the packages proposed**. **You could also add package(s) of interest based on your area of specialization on the blank pages and, answer for them appropriately (i.e. how much you would like to sell such packages).**

These packages are:

1. Improved seed varieties (certified seeds)-you are expected to come out with improved seed varieties from your research. These improved seeds could be any of the crops and vegetables grown in the three northern regions of Ghana: maize, rice, sorghum, millet, cowpea, tomatoes, okro, garden egg, etc. Such improved seeds have the attributes of high yielding, early maturing and, drought resistant.

2. Soil fertility management- providing training on techniques that include: knowledge on the type of fertilizer farmers should apply on crops, in what quantity and at what time in the crop life, knowledge on methods/ practices of improving soil fertility, knowledge on land conservation methods, knowledge on soil types and their respective suitable crops for cultivation.

3. Crop protection- the techniques under crop protection shall include training farmers on identifying the various types of insect pest and the crops that they mostly attack and, knowledge on preventive and control measures of field pest. Farmers are also supposed to be trained on crop disease identification and control measures.

4. Safe use of Agrochemicals- techniques under this include training farmers on the different types of agrochemicals available on the market, training on the right quantities to use, on what agents (insect-type, weed-type or crop-type) and how to use such agrochemicals.

5. Post-Harvest Technology- the techniques here include teaching farmers on the various storage pest and the specific crops that they attack, how to control them and what to use in controlling them.

6. Farm Management and Record Keeping- the techniques include teaching farmers on the importance of keeping records, types of records and, the art of keeping records, which is that you do not have to be literate to keep records. Thus non-literates can also keep records.

For farmers to have access to package one (1) (improved seeds), they can obtain them directly from you, seed growers or from agro-input shops in the market.

Also, for farmers to obtain any of the other packages (Soil fertility management, Crop protection, Safe use of Agrochemicals and Keeping of Farm records), you will need to organize a training programme for them at a designated venue or you visit them at their homes or farms.

For training programmes at designated venues, each farmer will pay for such training and will be responsible for his/ her cost of transportation and feeding. Farmers could be informed of such trainings through radio announcements, personal contacts, phone calls and/ or through their AEAs.

IMPORTANT NOTICE- The implementation of this policy (Commercializing innovations from agricultural research in the form of the various packages mentioned) is not a foregone conclusion; thus findings from research will still be available to farmers irrespective of the outcome of this Survey.

Thank you.

DEMOGRAPHIC DATA

1. Date of Interview ..... 2. Age of Respondent .....

3. Primary occupation .....4.Secondary occupation (if any).....

5. Your last academic qualification 1. PhD 2. MSc/ MPhil 3. BSc.

6. Membership of any professional body (e.g. Ghana Society of Horticulturalists, Ghana Science Association, Ghana Association of Agricultural Economists, etc)

1. Yes 0. No

7. If yes, state the name of the professional body

.....

.....

8. Number of years you have spent in agricultural research

.....

9. Number of publications, if any

10. Please your area of specialization in agricultural research (e.g. breeding, crop physiology & nutrition, etc.)? .....

FUNDING RESEARCH IN NORTHERN GHANA

F01. Which of the following is/ are the major sources of funding for your research activities **(Multiple Response is accepted)**

1. Donor funding

2. Government of Ghana (GoG)

3. Institution`s Internally Generated Funds (IGF)

4. Personal

.....

5. Others, please specify

F02. What is the percentage contribution of the various sources of funding to your research activities?

FUNDING SOURCE **% CONTRIBUTION (Total % should add up to 100%)**

1. Donor funding

2. ..... Government of Ghana (GoG) .....

3. ..... Internally Generated Funds (IGF) .....

4. ..... Personal

5. ..... Others, specify.....

F3 Based on your major source of funding for your research activities, in your opinion, has it been declining, remains same or increasing for the past five (5) years?

1. Declining 2. Same 3. Increasing

F4 If yes, please what is the percentage (%) of decline for the past five years? .....

F5 If no, please what is the percentage (%) of increase for the past five years? .....

SALE OF OUTPUT FROM RESEARCH ACTIVITIES AND POSSIBLE DETERMINING FGACTORS

S1 For the past five (5) years, have you sold any findings from your research or rendered any agric. Extension service for a fee?

1. Yes 0. No

S2 If Yes, to whom?

1. Farmers 2. Agro-processors 3. Others, please specify .....

S3 What are the specific research findings that you have sold or the specific agric. Extension services that you have rendered during the past five years?

1 .....

2 .....

S04. Has your institution benefited in terms of income from the sale of your research findings?

1. Yes 0. No

S05. If yes, what has been your percentage (%) share of such income accruing to your institution from the sale of research finding?.....

S06. Do you find your stated percentage share motivating for you to want to sell your research finding?

1. Yes 0. No

S07. What informs your research topic? (Multiple responses is accepted)

1. Donor requirements
2. Farmers` needs/ problems
3. Own perceived solutions to problems
4. Others, please specify

S08. Do you perceive the non-profit nature of extension delivery (Technology Transfer) to negatively affect the sale of research results?

1. Yes 0. No

S09. What is the level of collaboration between you and other researchers in the implementation of research projects?

1. Below Average 2. Average 3. Above Average

S10. Do you think collaboration with other researchers could help you in selling your research results?

1. Yes 0. No

S11. What is the main source of funding your salaries and emoluments?

1. Ghana Government (GoG) 2. Project Funds 3. Sales from research results

S12 In your opinion, does your dependence on your stated main source of funding your salaries and emoluments influence your commercialization drive?

1. Yes 0. No

S13 Will you be willing to sell your research results or provide agric. Extension service to farmers for a fee?

1. Yes 0. N0

S14 If yes, please state reasons for your answer?

.....

.....

S15 If no, please state reasons for your answer?

.....

S16 Do you think the necessity to publish in order to gain promotion instead of protecting findings from research for commercialization, can affect your commercialization drive?

1. Yes 0. No

VALUATION

If you were to sell your research results or provide training on the following packages, we would like to know the various amounts you will charge per farmer.

V01. What are the least amount and highest amount you would be willing to **charge per farmer** to provide a day`s training on soil fertility management?

LEAST AMOUNT (GH₵)	HIGHEST AMOUNT (GH₵)

V02. What are the least amount and highest amount you would be willing to **charge per farmer** to provide a day`s training on methods of weeds and insect pest control?

LEAST AMOUNT (GH₵)	HIGHEST AMOUNT (GH₵)

V03. What are the least amount and highest amount you would be willing to **charge per farmer** to provide a day`s training on safe use of agro-chemicals?

LEAST AMOUNT (GH₵)	HIGHEST AMOUNT (GH₵)

V04. What are the least amount and highest amount you would be willing to **charge per farmer** to provide a day`s training on post-harvest techniques?

LEAST AMOUNT (GH₵)	HIGHEST AMOUNT (GH₵)

V05. What are the least amount and highest amount you would be willing to **charge per farmer** to provide a day`s training on food procession techniques/ value addition?

LEAST AMOUNT (GH₵)	HIGHEST AMOUNT (GH₵)

V06. What are the least amount and highest amount you would be willing to **charge per farmer** to provide a day`s training on records keeping?

LEAST AMOUNT (GH₵)	HIGHEST AMOUNT (GH₵)

V07. What are the least amount and highest amount you would be willing to **charge for 1kg of improved seeds** of a specified crop that you breed?

IMPROVED SEED VARIETY	WORST AMOUNT (GH₵	BEST AMOUNT (GH₵)
1.e.g. Maize		
2.		
3.		
4.		
5.		

V08 which medium would you prefer in selling your research output to farmers?

V09. In your opinion, what are the possible challenges that you may face in the sale of innovations from

Research .....

THANK YOU VERY MUCH FOR YOUR TIME AND VALUABLE INPUT

FAMER LEVEL QUESTIONNAIRE

HYPOTHETICAL MARKET

There is a policy intention to provide research and extension services to farmers for a **fee.** Under such a policy regime, research and extension services will no longer be provided to farmers for **free**.

Prior to the implementation of such a policy, we would like to assess your willingness to pay for innovations from agricultural research.

For the purpose of this Study, we would like to assume that you as a farmer are faced with the following problems: lack of or inadequate access to certified seeds, less fertile soil, pest and diseases attack on your crops, problems with pest during crop storage and, lack of or inadequate knowledge on adding value to your farm produce. These problems have led to low yields and reduced income to you.

Under the new policy, you would be required to pay a researcher to obtain the following services in order to have the **benefit of higher yield and higher income.** These services are grouped in to packages and each package consists of a number of techniques. These packages are:

1. **Improved seed varieties (certified seeds)**-these seeds shall include all the crops that you grow: maize, rice, sorghum, millet, cowpea, tomatoes, okro, etc. These seeds are high yielding, early maturing and, drought resistant.

2. **Soil fertility management**- the techniques include: knowledge on the type of fertilizer to apply on crops, in what quantity and at what time in the crop life, knowledge on methods/ practices of improving soil fertility, knowledge on land conservation methods, knowledge on soil types and their respective suitable crops for cultivation.

3. **Crop protection**- the techniques under crop protection shall include identifying the various types of insect pest and the crops that they mostly attack, knowledge on preventive and control measures of field pest. Also inclusive are techniques on crop disease identification and control measures.

4. Safe use of Agrochemicals- techniques under this include knowledge on the different types of agrochemicals available on the market, understanding the right quantities to use, on what agents (insect-type, weed-type or crop-type) and how to use such agrochemicals.

5. Post-Harvest Technology- the techniques here include knowledge on the various storage pest that attack cereals and legumes, how to control them and what to use in controlling them.

6. Farm Management and record Keeping- the techniques include understanding the importance of keeping records, types of records and, the art of keeping records, which is that you do not have to be literate to keep records. Thus non-literates can also keep records.

To have access to package one (1) (certified seeds), you can obtain them directly from a researcher, seed growers or from agro-input shops in the market.

To obtain any of the other packages (Soil fertility management, Crop protection, Safety use of Agrochemicals and Keeping of Farm records), you will need to attend a training programme together with other farmers at a designated venue. You will be responsible for your cost of transportation and feeding.

DEMOGRAPHIC DATA

REGION .....DISTRICT .....

COMMUNITY .....

1. Name of Respondent ..... Sex...Tel: ...

2 Name of Enumerator .....3. Date of Interview: .....

4. Age.....5. Primary occupation: ..... Secondary occupation.....

6. Household Size:

7. Name of household head?

8. Educational status: 0. No formal education 1. Formal education

9. If formal education, number of years in school.....

10. Membership of a Farmer Based Organization (FBO): 1. Yes 0. No

11. Number of years in farming .....

12. Are you a native of this community? 1. Yes 0. No

13. If no, how long have you lived in this community? (in years)

14. In the 2013 cropping season, how many fields did you cultivate? .....

15. What was the total number of acres you cultivated for the 2013 cropping season? (**NB. Total acres of all crop fields**).....

S01 Did this household sell any crop produce from the 2013 cropping season? **0**. No **1**. Yes

(If No please skip to the next section)

S02 Please ask the farmer these questions and fill the table.

Crop sold	Year sold **2013=1 2014=2**	Month **1=Jan - 12=Dec**	Amount sold		Average price received	
			Quantity	Unit	Total sales (Ghana cedi)	Unit price (Ghana cedi)
S01	**S02**	**S03**	**S04**	**S05**	**S06**	**S07**

UNIT OF MEASURE

01-KG 03-100 KG BAG 04-90 KG BAG 04-50 KG BAG

NON-FARM INCOME

NFI01 Besides your farm produce, do you have any other source of income?

1. Yes 0. No

Activity Number	Economic activities	Fill with a ZERO if you did not get a cash income from the activity :	
		AMOUNT (GH₵)	Rank in order of economic value/income (e.g. 1-highest amount)
NFI01	**NFI02**	**NFI03**	**NFI04**
1	Horticultural crops and fruit sales		
2	Sale of products like milk, eggs		
3	Animal sales		
4	Fish sales		
5	Salaried work		
6	Self-employed activity outside of agriculture like trading, sale of charcoal, etc.		
7	Received remittances or pensions		
8	Casual labour		

If yes, and if your source of non-farm income includes any of the above, please state the total amount that you obtained from their sales for the 2013 cropping season

Seed system

SS01 Where did you obtain your seeds from for the 2013 cropping season?

1-Own farm **2**-Relatives **3**-Farmer group **4**-Research institution **5**-Seed growers **6**-NGO **7**-M0FA **8**- Agro-input shop **9**-Other (specify)_____

SS03 Are you satisfied with the quality of seeds usually available to you at planting time?

1- Yes **2**-S **0**-No

SS04 If you want a new variety where do you go to get its seeds?

1-Local farmers **2**-Farmers far away **3**-Seed growers **4**-Extension agents **5**-Research stations **6**-Markets **7**-Other (specify)

SSO5 Would you be willing to pay for any improved seed variety (certified seed)?
1- Yes **0**-No **(If No, please skip to SS06)**

If yes, what are the least amounts and highest amounts will you be willing to pay for **1Kg of certified seeds** of the following crops

IMPOVED CROP VARIETY	LEAST AMOUNT (GH₵/IKg)	HIGHEST AMOUNT (GH₵/IKg)
MAIZE		
RICE		
COWPEA		
SORGHUM		
TOMATOES		

SS06 If no, please state why.....

SOIL FERTILITY MANAGEMENT

SF01 Do you apply fertilizer (either organic or inorganic) on your crop fields?

1- Yes **0**-No

SF02 Have you ever been taught or had training on ways or methods of improving soil fertility for increased crop yield?

1- Yes **0**-No

SF03 Will you be willing to pay to receive training on ways or methods of improving soil fertility on your crop fields?

1- Yes **0**-No **(If No, please skip to SF07i)**

SF04 IF yes, what are the least amount and highest amount will you be willing to pay in order to receive such a training per sitting (i.e. a day`s training) on soil fertility management?

LEAST AMOUNT (GH₵/ a day)	HIGHEST AMOUNT (GH₵/ a day)

SF05 Assuming your friend is not able to pay to receive training on ways or methods of improving soil fertility on his crop fields, will you be prepared to share your knowledge with him/her for free? **1**- Yes **0**-No

SF06 If No, what percentage (%) of the amount you said you will be willing to spend on training will you ask him or her to pay? .....%

SF07i If No (**not willing to pay**), please state your reasons for your answer

.....

SF07ii Assuming you are not willing to pay, but your friend paid for training on soil fertility management, will you access such knowledge from him/ her for free?

1. Yes 0. No

SF07iii If No, what percentage (%) of the amount will you like to pay him or her?.....%

CROP PROTECTION

CP01 Please are you aware that insect pests and weeds reduce both the quantity and quality of crop yield?

1- Yes **0**-No

CP02 Have you ever been taught or had training on ways or methods of Insect Pest Control on your crop fields?

1- Yes **0**-No

CP03 Will you be willing to pay to receive training on ways or methods of controlling weeds and insect pest on your crop fields?

1- Yes **0**-No (**If No, please skip to CP07i**)

CP04 IF yes, what are the least amount and highest amount will you be willing to pay in order to receive such a training per sitting (i.e. a day`s training) on methods of weeds and insect pest control?

LEAST AMOUNT (GH₵/ a day)	**HIGHEST AMOUNT (GH₵/ a day)**

CP05 Assuming your friend is not able to pay to receive training on ways or methods of controlling weeds and insects on his crop fields, will you be prepared to share your knowledge with him/her for free?

1- Yes **0**-No

CP06 If No, what percentage (%) of the amount you paid will you ask him or her to pay? .....%

CP07i If No (**not willing to pay**), please state your reasons for your answer

.....

CP07ii Assuming you are not willing to pay, but your friend paid for training on controlling weeds and insect pest, will you access such knowledge from him/ her for free?

1. Yes 0. No

CP07iii If No, what percentage (%) of the amount will you pay him/ her?.....%

CP08 Please are you aware that the use of agrochemicals (weedicides & insecticides) can be harmful to your health and the environment?

1- Yes **0**-No

CP09 Will you be willing to pay to receive training on the safe use of agrochemicals?

1- Yes **0**-No (**If No, please skip to CP13i**)

CP10 IF yes, what are the least amount and highest amount you will be willing to pay in order to receive such a training per sitting (i.e. a day`s training) on safe use of agrochemicals?

LEAST AMOUNT (GH₵/ a day)	**HIGHEST AMOUNT (GH₵/ a day)**

CP11 Assuming your friend is not able to pay to receive training on the safe use of agro-chemicals, will you be prepared to share your knowledge with him/her for free?

1- Yes **0**-No

CP12 If No, what percentage (%) of the amount will you ask him or her to pay? .....%

CP13i If No (**not willing to pay**), please state your reasons for your answer

.....

.....

CP13ii Assuming you are not willing to pay, but your friend paid for training on the safe use of agro-chemicals, will you access such knowledge from him/ her for free?

1. Yes 0. No

CP13iii If No, what percentage (%) of the amount will you pay him/ her? .....%

CP14 Do you use protective clothing when spraying your fields with agro-chemicals?

1. Yes **0**. No

FCD01 Will you be willing to pay to receive training on the prevention and control of field crop diseases?

1- Yes **0**-No (**If No, please skip to FCD05i**)

FCD02 IF yes, what are the least amount and highest amount you will be willing to pay in order to receive such a training per sitting (i.e. a day`s training) on the prevention and control of field crop diseases?

LEAST AMOUNT AMOUNT (GH₵/ a day)	**HIGHEST AMOUNT (GH₵/ a day)**

FCD03 Assuming your friend is not able to pay to receive training on the prevention and control of field crop diseases, will you be prepared to share your knowledge with him/her for free?

1- Yes **0**-No

FCD04 If No, what percentage (%) of the amount will you ask him or her to pay?.....%

FCD05i If No (**not willing to pay**), please state your reasons for your answer

.....

.....

FCD05ii Assuming you are not willing to pay, but your friend paid for training on the prevention and control of field crop diseases, will you access such knowledge from him/ her for free?

1. Yes 0. No

CP05iii If No, what percentage (%) of the amount will you pay him/ her? ..... %

POST- HARVEST TECHNOLOGY AND VALUE ADDITION

PH01 Do you have problems with insect pest during storage of your farm produce?

1- Yes **0**-No

PH02 Will you be willing to pay to receive training on post-harvest techniques which can help increase the shelf life of your farm produce?

1- Yes **0**-No (**If No, please skip to PH06i**)

PH03 IF yes, what are the least amount and highest amount you will be willing to pay in order to receive such a training per sitting (i.e. a day`s training) on post-harvest techniques?

LEAST AMOUNT (GH₵/ a day)	**HIGHEST AMOUNT (GH₵/ a day)**

PH04 Assuming your friend is not able to pay to receive training on post-harvest techniques, will you be prepared to share your knowledge with him/her for free?

1- Yes **0**-No

PH05 If No, what percentage (%) of the amount will you ask him or her to pay? ..... %

PH06i If No (**not willing to pay**), please state your reasons for your answer

.....

PH06ii Assuming you are not willing to pay, but your friend paid for training on post-harvest techniques, will you access such knowledge from him/ her for free?

1. Yes 0. No

PH06iii If No, what percentage (%) of the amount will you pay him/ her? ..... %

PH07 Will you be willing to pay to receive training on food procession methods for the purpose of adding value to your farm produce to increase your income?

1- Yes **0**-No (**If No, please skip to PH11i**)

PH08 IF yes, what are the least amount and highest amount will you be willing to pay in order to receive such a training per sitting (i.e. a day`s training) on food procession techniques?

LEAST AMOUNT (GH₵/ a day)	**HIGHEST AMOUNT (GH₵/ a day)**

PH09 Assuming your friend is not able to pay to receive training on food procession techniques, will you be prepared to share your knowledge with him/her for free?

1- Yes **0**-No

PH10 If No, what percentage (%) of the amount will you ask him or her to pay? .....%

PH11i If No (**not willing to pay**), please state your reasons for your answer

.....

.....

PH11i Assuming you are not willing to pay, but your friend paid for training on food procession techniques, will you access such knowledge from him/ her for free?

1. Yes 0. No

PH11i If No, what percentage (%) of the amount will you pay him/ her? .....%

FARM RECORDS

FR01 Do you keep records on your farming activities?

1- Yes **0**-No

FR02 Will you be willing to pay to receive training on records keeping to improve your management skills as a farmer?

1- Yes **0**-No (**If No, please skip to FR06i**)

FR03 IF yes, what are the least amount and highest amount you will be willing to pay in order to receive such a training per sitting (i.e. a day`s training) on records keeping?

LEAST AMOUNT (GH₵/ a day)	HIGHEST AMOUNT (GH₵/ a day)

FR04 Assuming your friend is not able to pay to receive training on records keeping; will you be prepared to share your knowledge with him/her for free?

1- Yes **0**-No

FR05 If No, what percentage (%) of the amount will you ask him or her to pay?

FR06i If No (**not willing to pay**), please state your reasons for your answer

.....

.....

FR06ii Assuming you are not willing to pay, but your friend paid for training on records keeping, will you access such knowledge from him/ her for free?

1. Yes 0. No

FR06iii If No, what percentage (%) of the amount will you pay him/ her?.....%

RC01 Please, we would like to ask you again, the various technologies mentioned (improved seed, soil fertility management techniques, weeds and pest control methods, etc.), if you have free access to them from friends and relatives, will you still be willing to pay for them from extension or research?

1-Yes 0-No

RC02 Please, choose one of the following media through which you can say has created much awareness on you concerning innovations from agriculture

1-Field demonstrations 2-Contact with NGOs 3- Local FM stations 4-Contact with A.E.As 5-others (specify) .....

RC03 Do you have some challenges as a farmer that you will like current research to look in to?

1- Yes **0**-No

RC04 If yes, please mention those challenges

THANK YOU VERY MUCH FOR YOUR TIME

Appendix 1 Correlations between willingness to pay for innovations from research

TECHNOLOGIES	Improved seeds	Soil fertility improvement techniques	Weed and pest control management technique	Safe-use of agro-chemicals	Crop disease identification and control methods	Post-harvest techniques	Farm management and record keeping
Improved seeds	1						
Soil fertility management techniques	0.5900	1					
Weed and pest control management technique	0.5788	0.6536	1				
WTP for safe use of agro-chemicals	0.4534	0.5022	0.6804	1			
Crop disease identification and control methods	0.2820	0.2945	0.4311	0.4213	1		
post-harvest techniques	0.1884	0.2663	0.3574	0.3078	0.2296	1	
farm management and record keeping	0.0184	0.0211	0.0691	0.0236	0.0261	0.0519	1

Appendix 2 Matrix for Objectives, Methods, Key findings, Conclusions, Implications and Policy Recommendations

Objectives	Method of analysis	Key findings	Conclusions	Implications	Recommendations
To determine how much researchers would be willing to sell innovative technologies to farmers	C. V. Descriptive statistics: Mean values	Researchers were willing to sell between GH₵43.00 and GH₵57.00 for research innovations	Among researchers, there were different valuations for research innovations	This is a reflection of how much value researchers attach to these technologies	Research commercialization can be fully implemented. However it must not be the sole source of funding to research. Researchers are also encouraged to patent their innovations.
To determine how much farmers would be willing to pay for innovative technologies	C. V. Descriptive statistics: Mean values	On average, farmers were willing to pay GH₵6.00 for improved technologies	Most farmers were willing to pay for innovations from research	This is a reflection how much value farmers attach to research innovations and their WTP to maintain supply of these innovations.	Research institutions, MoFA and NGOs should encourage farmers to pay for research innovations. They should also make such innovations affordable to farmers.
To investigate possible factors that can influence the sale of research output in northern Ghana	Probit analysis	Younger researchers are more willing to sell innovations from research. Number of publications of researchers and their membership to professional bodies will positively influence research commercialization	On the supply side, the success of research commercialization will be dependent on improvements in the number of research publications, youth in academia going into research	Youthfulness, networking among scientists and increased scientific productivity could be drivers of research commercialization from the supply side.	There should be a policy to attract young academics into research. Researchers from Research institutions should be encouraged to be members to professional bodies, both local and foreign. Promotions for researchers should continue to be based on number of publications.
To examine the potential factors that may affect farmers'	Multivariate probate analysis	Older farmers were less WTP for improved technologies. Educational status of farmers, farm and non-	Improvement in socio-economic conditions of farmers will positively enhance WTP for most research	The involvement of the youth in agriculture and improvements in education, farm and non-farm incomes will be	The youth should be encouraged to go into farming. Policy makers should take keen interest in improving farm

WTP for improved technologies		farm income as well as extension contacts had positive influence on WTP.	innovations.	critical to the success of research commercialization.	and non-farm income of farmers. Government and NGOs should engage more AEAs.

Appendix 3 Distribution of farmers sampled; by regions, districts and communities

REGION	DISTRICT	COMMUNITY	NO. OF FARMERS
Upper East	Bolga Municipal	Bolga Foe	10
		Bukeri	10
		Yepala	10
		Yorogo-tingre	10
		Zaare	10
		Nyariga	10
	Bongo	Vea	10
		Gowrie	10
		Dua	10
		Kunkua	10
		Balungu	10
		Lungo	10
Upper West	Wa East	Motigu	10
		Tousah	10
		Jeyiri	10
		Bulenga	10
		Tiisa	10
		Kulkpong	10
	Lambussie-Karni	Gbal	10

		Chum	10
		Naawie	10
		Samoa	10
		Lambusie	10
		Suke	10
Northern Region	Yendi	Worvi	10
		Jagrido	10
		Puriya	10
		Kpabia	10
		Choo	10
		Sorbitido	10
	Tolon	Nafram	10
		Tuunayili	10
		Tingoli	10
		Kpachi	10
		Kpalisogu	10
		Worebogu Kukuo	10
TOTAL	**6**	**36**	**360**

Appendix 4 Probit indicating factors influencing farmers' WTP for innovations

Explanatory Variables	Improved Seed	Soil Fertility Improvement techniques	Weeds and Insect Pest control methods	Safe use of agro-chemicals	Crop Diseases identification and Control Measures	Farm Management and Record Keeping	Post-Harvest Techniques
	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Age	-0.0222541 (0.0083612)***	-0.0285107 (0.0081633)***	-0.0294915 (0.0092794)***	-0.0487716 (0.0100546)***	-0.003401 (0.0085466)	-0.0061457 (0.0060389)	-0.0213486 (0.007623)***
Educational Status	0.8566023 (0.4063613) **	-0.0004373 (0.2269114)	-0.0898358 (0.2734372)	-0.4790022 (0.2654224)*	-0.0351378 (0.2238314)	0.430929 (0.1556653)***	-0.144377 (0.2155912)
Nativity	0.8973799 (0.2481937)***	0.7725424 (0.2414772)**	0.8741929 (0.2820333)***	0.2542582 (0.313295)	-0.4626531 (0.342405)	-0.0029226 (0.2138322)	0.0818802 (0.2621454)
Free-Rider	0.4872093 (0.2353743)**	0.4128067 (0.2207351)*	0.4746116 (0.2559607)*	0.4662275 (0.2736648)	0.2228686 (0.2347527)	0.3498178 (0.1878753)*	0.5004964 (0.211285)**
Number of Acres	0.0130904 (0.0227986)	0.0121588 (0.020583)	0.0471642 (0.0303452)	0.0633813 (0.0348181)*	0.0264265 (0.0225748)	-0.081843 (0.0134122)	0.0048097 (0.0175745)
Off-Farm Income	0.0130904 (0.0001053)	-0.0001431 (0.0000467)***	-0.0001078 (0.000062)*	9.89e-07 (0.0000751)	-0.0000177 (0.0000666)	-0.000032 (0.0000453)	-0.0000106 (0.0000543)
Farm Income	0.0001169 (0.0001506)	0.0000733 (0.0000963)	0.0005268 (0.0002579)**	0.0005268 (0.0002799)*	0.0000717 (0.0001585)	0.0000625 (0.0000699)	-0.000062 (0.0000686)
Number of contact with an A.E.A.	0.0552829 (0.32997)*	-0.0308932 (0.0245868)	-0.047721 (0.0259496)*	-0.0610719 (0.0257548)**	-0.0208771 (0.0251704)	0.0867617 (0.0174427)***	0.0043998 (0.0253028)

Multivariate Probit (SML, # draws = 30 — Number of observations = 360

Log Likelihood = -550.02745 — Wald chi-square = 143.44 — Prob > chi-square (0.000)

*, **, *** represent 10%, 5% and 1% levels of significance respectively.

NB. Std. Errors are in Parenthesis.

Source: MV Probit results from computation based on field data (2014)