UNIVERSITY OF CAPE COAST

COCOA RESEARCH INNOVATIONS AND OUTPUT IN GHANA

BY

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DECLARATION

Candidate's Declaration

I hereby declare that this 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.

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Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

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ABSTRACT

Cocoa Research Institute of Ghana has introduced a number of innovations to increase cocoa yield per hectare from 360 to 1,300 Kg but the rate of adoption has been low. The objectives of the study were to determine factors which influence adoption and to estimate the impact of adoption on output. A sample of 600 cocoa farmers was selected through a multistage sampling technique. An interview schedule was used to gather data. The double hurdle model was used to estimate the determinants of adoption and intensity of adoption whilst OLS was used to estimate the impact of adoption on output.

Findings were that age of the farmer negatively affected adoption. Household size, farm size, primary education, access to credit, hired labour, non-hired labour, own labour, membership of association and frequency of extension advice positively influenced adoption. The results further indicated that all the variables had positive relationship with intensity of adoption. Also, output of cocoa had positive relationship with household size, farm size, middle school education, hired labour, membership of association, frequency of extension advice, credit access and intensity of adoption.

It is recommended that government should tackle the issue of land ownership: COCOBOD should intensify provision of social interventions like the housing scheme for cocoa farmers to make farming attractive to the youth, intensify extension services, provide training and encourage them to join farmer associations. Lastly financial institutions should educate farmers on requirements to access credit and the need to repay loans granted.

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DEDICATION

To my family

TABLE OF CONTENTS

Content | Page

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

AE	Allocative Efficiency
CAA	Cocoa Abrabopa Association
CHTP	Cocoa High Technology Programme
COCOBOD	Ghana Cocoa Board
CODAPEC	Cocoa Diseases and Pest Control
COLS	Corrected Ordinary Least squares
CRIG	Cocoa Research Institute of Ghana
CRIN	Cocoa Research Institute of Nigeria
CS Pro	Census and Survey Processing System
CSAE	Centre for the Study of African Economies
CSSVD	Cocoa Swollen Shoot Virus Disease
DEA	Data Envelopment Analysis
DOI	Diffusion of Innovations
ERP	Economic Recovery Programme
EU	European Union
FAO	Food and Agriculture Organization
FASDEP	Food and Agricultural Sector Development Policy
FE	Fixed Effects
FOB	Free on Board
GCFS	Ghana Cocoa Farmers Survey
GDP	Gross Domestic Product
GHC	Ghana Cedis
GLS	Generalized Least Squares

GLSS	Ghana Living Standards Survey
HYVs	High-Yielding Varieties
IEBM	International Encyclopaedia of Business and Management
IFPRI	International Food Policy Research Institute
ILO	International Labour Organization
ISSER	Institute of Statistics Social and Economic Research
JSS	Junior Secondary School
LBCs	Licensed Cocoa Buying Companies
ML	Maximum Likelihood
MLE	Maximum Likelihood Estimates
MMYE	Ministry of Manpower, Youth and Employment
MOF	Ministry of Finance
MOFA	Ministry of Food and Agriculture
MV	Modern Variety
OLS	Ordinary Least Squares
PATCA	Program for Technological Support in the Agricultural
RE	Random Effects
REH	Rational Expectation Hypothesis
SSS	Senior Secondary School
TAM	Technology Acceptance Model
TE	Technical Efficiency
TFP	Total Factor Productivity
TOE	Technology, Organization and Environment
TORA	Theory of Reasoned Action
TPB	Theory of Planned Behaviour

TSLS	Two Stage Least Squares
TT	Tornqvist Theil
UNCTAD	United Nations Conference on Trade and Development
UTAUT	Unified Theory of Acceptance and Use of Technology.
VPD	Vapour Pressure Deficits
WACAP	West Africa Cocoa and Commercial Agriculture Programme
WACRI	West Africa Cocoa Research Institute
WLS	Weighted Least Squares

CHAPTER ONE

INTRODUCTION

Background to the study

Ghana attained political independence in 1957 and by then its per capita income was at about the same level as that of Malaysia, Indonesia, Mexico or South Korea (Sowa, 1993). However, Ghana is now considered a lower middle income country whereas Malaysia, South Korea and Indonesia are considered as developed countries.

According to Naya and McCleery (1994), the Asian countries such as Japan, Hong Kong, South Korea, Singapore, Taiwan, Malaysia and Thailand were able to grow according to their underlying potential by eliminating four fundamental challenges of development namely the agricultural gap, the human resource development gap, the savings and investment gap and the foreign exchange gap. They opine that the Green Revolution and its new technologies such as the use of abundant water and fertilizer helped to generate high yield and thus economized on the scarce land and bridged the agricultural (basic need) gap. Also, investment in human resource development provided the needed manpower with the required skills and thus bridged the human resource development gap. Furthermore, the mobilization of domestic savings, development of financial intermediation, and incentive for productive investment played a critical role in Asian development. They believed that effective management of foreign exchange resources and incentives to potential producers of foreign exchange contributed significantly to the development of the Asian countries.

McConnell and Brue (2002) have also observed that technological advancement is a critical engine of productivity growth. They defined technology as 'the body of knowledge and techniques that can be used to combine economic resources to produce goods and services'. They further explained that technology can refer to material objects of use to humanity such as machines, hardware or utensils, but it can also encompass broader themes including systems, methods of organization and techniques. They added that technological advancement includes not only innovative production techniques but new and managerial methods and new forms of business organization that improves the production process. They hold the view that generally technological advancement is generated by the discovery of new knowledge, which allows for resources to be combined in improved ways that increase output.

According to Rogers (2003) technology and innovation are often used synonymously. He defines technology as a design for instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving an outcome. He identified two components of technology namely a hardware aspect which consists of the tool that embodies the technology as well as material or physical object, and a software aspect consisting of the information base for the tool.

There is no gain saying that firms and countries which adopt improved technologies are able to increase output and realize the benefits associated with increased production. Farmers in Ghana will therefore be able to increase their output if they adopt improved agricultural technologies, other things being equal.

The Ghanaian economy depends largely on primary production in agriculture with the cocoa sector being the most dominant. Agriculture's contribution to Gross Domestic Product (GDP) increased from 33.9% in 2008 to 34.5% in 2009. The major contributors to agricultural foreign exchange earnings are cocoa, timber and non-traditional agricultural exports. The contribution of cocoa to total foreign exchange earning was 31.1% in 2009 and 22.5% in 2011. The contributions from timber and non-traditional exports to total foreign exchange earnings in 2011 were 1.3% and 2.3% respectively. (ISSER, 2012, p111). To be able to significantly improve agricultural output especially cocoa, there is the need for modification of the production techniques through the adoption of modern technology conducive to the Ghanaian environment.

The cocoa sector employs about 24% of the labour force (FASDEP, 2002) and contributed about 4.5% of the gross domestic product in 2007 (CSAE, 2009). According to the Report of the Fifth Round of the Ghana Living Standards Survey (GLSS, 2008) about 725,480 households are involved in cocoa production. Cocoa contributed about 24.4% of the total export earnings in 2009 (ISSER, 2010). Also, the cocoa sector contributes to educational development of the country as scholarships are granted to the children of cocoa farmers. Besides, there have been a number of infrastructural developments such as provision of roads and hospitals from revenue obtained from the cocoa sector. The sector therefore contributes to the development of the country. Details of contribution of cocoa to the Ghanaian economy are provided in Appendices A to E.

Ghana was the largest exporter of cocoa beans in the world from 1911 until 1978 when La Cote d'Ivoire overtook it (Awuah, 2002). According to Dormon et al (2004) cocoa production levels declined from 568,000 metric tonnes in 1965 to its lowest level of 160,000 metric tonnes in 1983. The decrease in the 1980s was attributed to adverse weather conditions that led to widespread bush fire destroying many cocoa farms. The number of households in cocoa production has been increasing significantly as shown in Table 1 but the rate of increase in output of cocoa has not been high. However, since the mid 1980s production levels have risen gradually to 1,024,600 metric tonnes in 2010/11 season (ISSER, 2012).

Table 1: Households harvesting cocoa in Ghana

Year	Survey	Coastal	Forest	Savannah	Total
1991/92	GLSS3	40,000	340,000	-	380,000
1998/99	GLSS 4	48,000	575,300	20,300	584,400
2005/06	GLSS 5	56,780	651,009	17,691	725,480

Source: Ghana Statistical Service, 1995, 2000 & 2008

Statement of the problem

Dormon, Huis, Leeuwis, Obeng-Ofori and Sakyi-Dawson (2004) have indicated that generally yields of cocoa are lower in Ghana than in other major producing countries. Whilst average cocoa yield in Malaysia is 1,800 kilogram per hectare and 800 kilogram per hectare in la Cote d'Ivoire, it is only 360 kilograms per hectare in Ghana. They gave reasons for the low productivity as poor farm maintenance practices, planting low-yielding varieties, and the incidence of pests and diseases.

According to a preliminary report on baseline survey of sustainable development for cocoa farmers in Ghana by Hainmuelier, Hiscox and Tampe (2011), median cocoa yield in Kilogram per hectare in the Ashanti, Brong Ahafo, Central, Eastern and Western regions is as shown in Table 2. The report indicates that the highest yield per hectare is 389 Kilograms.

Table 2: Average yield of cocoa per hectare according to regions

Region	Median Cocoa Yield (Kilogram per Hectare)
Ashanti	382
Brong Ahafo	389
Central	355
Eastern	374
Western	389

Source: Hainmuelier J, Hiscox, M.I & Tampe, M (2011) Sustainable Development for Cocoa Farmers in Ghana. MIT & Harvard University, Page 21.

It is worth noting that in Ghana there is no distinction between cocoa output and purchases because whatever that is produced is purchased by COCOBOD. Thus, in 2010/11 season for example the total purchase of 1,024,541 tons can be regarded as the total output. Total export for the same period was 630,000 tons because some of the beans were processed locally.

The Cocoa Research Institute of Ghana (CRIG) formerly West African Cocoa Research Institute (WACRI), a division of Ghana Cocoa Board (COCOBOD) and located at Akim Tafo was established in 1938 to investigate disease and pests which had considerably reduced cocoa production in the West African sub-region. WACRI was changed to CRIG in 1962 after Ghana and Nigeria attained independence from colonial rule. CRIG has undertaken many studies and introduced a number of programmes including introduction of hybrid cocoa and the Cocoa High Technology Programme (Hi-tech). The Hi-Tech programme emphasizes the use of fertilizer and proper farm management practices to achieve higher cocoa yield. However to enable maximum utilization of the fertilizer the programme holistically consists of other four components namely cultural maintenance, application of fungicides, application of insecticides and harvesting, fermentation and drying technologies in addition to the fertilizer application component. Results indicated that yield per hectare increased from 360 Kilograms to 1,300 Kilograms (Appiah, Ofori-Frimpong, Afrifa & Asante, 1997). The details of the contribution of CRIG to the cocoa sector are presented in Chapter Two.

Teal and Vigneri (2004) conducted a survey of Ghana cocoa farmers to obtain panel data set for Ghana Cocoa Board. Their finding was that cocoa output increased from 340,502 tons in 2001/2002 to 736,975 in 2003/04. The increase in output was attributed to extensive expansion in farms in Western Region where the price of land was relatively low, increase in non-labour input such as fertilizers and increase in the number of person day on the farm. The study focused on two policy variables which were the provision of spraying machines by government and the degree of market power exercised at the village level by the licensed buying companies (LBCs).

In a related study, Vigneri (2007) attributed the increase in cocoa output in Ghana between 2001 and 2003 to the increase in fertilizer use and a government sponsored mass-spraying exercise beginning 2001. He observed that farmers are progressively integrating fertilizer use and spraying practices into their own cultivation of cocoa crop. He indicated that two thirds of the increase in production was generated from extensive land margin while the other third was obtained by intensifying productivity of existing land under cultivation. The survey indicated that cocoa production is characterised by low technology cultivation which requires the use of working capital mainly to hire labour for clearing and weeding the land, to purchase the chemicals needed to spray cocoa farms for the control of pests and disease.

Vigneri (2007) identified the determinants of cocoa output as land, labour, fertilizer, insecticide, agricultural equipment, rainfall, male cocoa farmer, use of spraying machine and percentage loss of land to black pod disease. He explained that the amount of land greatly affected production due to bringing in virgin land for cultivation. Also, labour and fertilizer use coupled with the extensive use of spraying machine also resulted in increased production. He concluded that the adoption of substantially higher fertilizer rates in conjunction with a systematic spraying of cocoa farms has played a key role in sharing the potential of market incentives in making possible what is considered a miracle of growth episode.

One of CRIG's findings about factors militating against cocoa production was the improper use of fertilizer. They identified that soil nutrients are the main source of nutrient supply to cocoa trees in Ghana and that the non compensated use of nutrients has led to degraded soil fertility in cocoa growing areas and consequential decline in production. Consequently, CRIG came out with proper application of fertilizer and results indicated that yield per hectare increased from about 360 Kilograms to 1,300 Kilograms (Appiah et al, 1997). However despite this finding some cocoa farmers are not taking advantage of this technology.

The foregoing indicates that outcome of research findings have been mixed. Boahene, Snijders and Folmer (1999) observed that technological innovations in Ghana have taken place in the cocoa sector. One of these innovations is the introduction of hybrid cocoa which appears to have higher productivity than other varieties such as Amazon and Amelonado. However, according to Boahene et al (1999) only 10% of farmers had adopted this variety of cocoa as at 1999 due to both economic and sociological factors. Factors such as bank loans and hired labour had significant positive impact on adoption.

Researchers such as Teal and Vigneri (2004) have attributed 66% of increase in cocoa output to farm expansion in virgin forests and the remaining 34% to increase in fertilizer application. Virgin lands are being depleted and there is the need to increase yield per acre of existing lands through fertilizer application. Appiah et al (1997) observed that whereas estimated yield in Ghana was 400 Kilogram per hectare actual yield of CRIG experimental farm was over 1,300 Kilograms per hectare.

Aneani, Anchirinah, Owusu-Ansah and Asamoah (2012) in their study of adoption of some cocoa production technologies by cocoa farmers in Ghana estimated adoption rates for control of capsids with insecticides, control of black pod disease with fungicides, weed control manually or with herbicides, planting hybrid cocoa varieties and fertilizer application as 10.3%, 7.5%, 3.7%, 44% and 33% respectively.

In summary, the problem is that fresh land for cocoa cultivation is getting exhausted. Soils in existing farms are becoming less fertile due to drawing of nutrients by the cocoa trees. Fortunately, CRIG has come out with technologies which will improve yield in existing farms without necessarily increase farm sizes. However, adoption rates have been low. There is therefore the need to investigate the need why farmers are not adopting the technologies.

Research questions

In the light of the above the study seeks to address the following questions: what are the determinants of adoption of cocoa research innovations? What factors affect the intensity of adoption of cocoa research innovations? What is the impact of intensity of adoption of cocoa research innovations on output of cocoa?

Objectives of the study

The main objective of the study is to determine the factors influencing adoption and their impact on cocoa output in Ghana. Specific objectives of the study are to:

1. determine factors which affect adoption of cocoa research innovations in Ghana.

2. investigate the major determinants of adoption of cocoa research innovations in Ghana.
3. estimate the effects of intensity of adoption of cocoa research innovations and other farmer characteristics on output.

Hypotheses

In line with the stated objectives, there will be three models with hypotheses to be tested.

Model 1: Determinants of adoption

1. H_0: There is no relationship between farmer's age and adoption of cocoa research innovations.

   H_1: The age of the farmer is negatively related to adoption of cocoa research innovations.

2. H_0: There is no relationship between household size and adoption of cocoa research innovations.

   H_1: The household size is positively related to adoption of cocoa research innovations.

3. H_0: There is no relationship between farm size and adoption of cocoa research innovations.

   H_1: The farm size is positively related to adoption of cocoa research innovations.

4. H_0: There is no relationship between level of formal education and adoption of cocoa research innovations.

   H_1: The level of formal education is positively related to adoption of cocoa research innovations.

5. H_0: There is no relationship between availability of labour (hired labour, non-hired labour and own labour) and adoption of cocoa research innovations.

   H_1: The availability of labour (hired labour, non-hired labour and own labour) is positively related to adoption of cocoa research innovations.

6. H_0: There is no relationship between membership of an association and adoption of cocoa research innovations.

   H_1: Membership of an association is positively related to adoption of cocoa research innovations.

7. H_0: There is no relationship between extension advice and adoption of cocoa research innovations.

   H_1: Extension advice is positively related to adoption of cocoa research innovations.

8. H_0: There is no relationship between credit access and adoption of cocoa research innovations.

   H_1: Credit access is positively related to adoption of cocoa research innovations.

Model 2: Determinants of Intensity of Adoption

1. H_0: There is no relationship between farmer's age and intensity of adoption of cocoa research innovations.

   H_1: The age of the farmer is negatively related to intensity of adoption of cocoa research innovations.

2. H_0: There is no relationship between household size and intensity of adoption of cocoa research innovations.

H_1: The household size is positively related to intensity of adoption of cocoa research innovations.

3. H_0: There is no relationship between farm size and intensity of adoption of cocoa research innovations.

   H_1: The farm size is positively related to intensity of adoption of cocoa research innovations.

4. H_0: There is no relationship between level of formal education attainment and intensity of adoption of cocoa research innovations.

   H_1: The level of formal education is positively related to intensity of adoption of cocoa research innovations.

5. H_0: There is no relationship between availability of labour (hired labour, non-hired labour and own labour) and intensity of adoption of cocoa research innovations.

   H_1: The availability of labour (hired labour, non-hired labour and own labour) is positively related to intensity of adoption of cocoa research innovations.

6. H_0: There is no relationship between membership of an association and intensity of adoption of cocoa research innovations.

   H_1: Membership of an association is positively related to intensity of adoption of cocoa research innovations.

7. H_0: There is no relationship between extension advice and intensity of adoption of cocoa research innovations.

   H_1: Extension advice is positively related to intensity of adoption of cocoa research innovations.

8. H_0: There is no relationship between credit access and intensity of adoption

of cocoa research innovations.

H_1: Credit access is positively related to intensity of adoption of cocoa research innovations.

Model 3: Impact of Intensity of Adoption on Cocoa Output

1. H_0: There is no relationship between farmer's age and cocoa output.

   H_1: The age of the farmer is negatively related to cocoa output.

2. H_0: There is no relationship between household size and cocoa output.

   H_1: The household size is positively related to cocoa output.

3. H_0: There is no relationship between farm size and cocoa output.

   H_1: The farm size is positively related to cocoa output.

4. H_0: There is no relationship between the level of formal education and cocoa output.

   H_1: The level of formal education is positively related to cocoa output.

5. H_0: There is no relationship between availability of labour (hired labour, non-hired labour and own labour) and cocoa output.

   H_1: The availability of labour (hired labour, non-hired labour and own labour) is positively related to cocoa output.

6. H_0: There is no relationship between membership of an association and cocoa output.

   H_1: Membership of an association is positively related to cocoa output.

7. H_0: There is no relationship between extension advice and cocoa output.

   H_1: Extension advice is positively related to cocoa output.

8. H_0: There is no relationship between credit access and cocoa output.

   H_1: Credit access is positively related to cocoa output.

9. H_0: There is no relationship between intensity of adoption of cocoa research innovations and cocoa output.

H_1: There is a positive relationship between intensity of adoption of cocoa research innovations and cocoa output.

Significance of the study

The study is of methodological and policy relevance. With regard to methodology, the double hurdle model used in this study has not been applied in the study of adoption of cocoa research innovations in Ghana. The literature review indicates that the logit, probit and tobit models have been mostly used to study technology adoption in Ghana. The double hurdle model is considered superior as it is capable of handling both the decision to adopt and intensity of adoption simultaneously. Thus, the study has contributed to the methodology for researching into technology adoption.

Also, the study is of policy relevance. The factors which significantly affect adoption of cocoa research innovations have been identified and these will inform policy decision to influence increased output of cocoa in Ghana. Above all, the study will contribute to the existing stock of knowledge on the determinants of adoption and the impact of technology adoption on output.

Scope of the scope

The study covers three major themes. The first and second are the determinants of adoption and intensity of adoption. There are many determinants of adoption but based on literature review and theoretical framework, this study limited itself to the following factors: age of the farmer, household size, farm size, farmers' level of education, access to credit, membership of association, frequency of extension advice, hired labour, non-hired labour and farmers' own labour. Intensity of adoption measured the degree of adoption of recommended cocoa cultural practices such as weeding, pruning semi-parasitic mistletoe plant, fertilizer application, harvesting, fermentation and drying of cocoa. The double hurdle model was used in estimating the determinants of adoption and intensity of adoption.

The third theme of the study dealt with the impact of adoption on output. The dependent variable was logarithm of total output per acre and the main independent variable of interest was intensity of adoption. However, other variables such as the age of the farmer, household size, educational level, number of children in the family, hired labour, non-hired labour, own labour, membership of association, frequency of advice from extension officers were included. The ordinary least squares method was used in the estimation with credit and farm size being instruments for intensity of adoption.

The population for the study was all cocoa farmers in Ghana. In terms of geographical area, it covered five cocoa regions namely Ashanti, Brong Ahafo, Central, Eastern and Western. The Volta region was not included because output of cocoa from that region which was 3,286 tons in 2010/2011 was less than one percent of the total national output of 1,024,553 tons (COCOBOD, 2011). Ten (10) cocoa districts were selected from the various regions because it was impossible to include all the sixty nine (69) cocoa districts in Ghana.

Organisation of the study

The study is divided into nine chapters. Chapter One deals with background to the study, statement of the problem, objectives of the study, hypotheses to be tested, significance of the study, scope of the study and outline of the study.

Chapter Two treats the history of cocoa production in Ghana. It deals with the origin of cocoa, varieties of cocoa, technical characteristics and history of commercial cultivation of cocoa in Ghana. It also considers the role of the Cocoa Research Institute of Ghana (CRIG) in the cocoa industry. Furthermore, it deals with the establishment of CRIG, its mandate, mission, objectives, organisational structure and innovations introduced in the cocoa industry. The various policy interventions in the cocoa sector, environmental conditions, areas under cultivation, method of cultivation and the various policy interventions in the cocoa sector are discussed in this chapter. Also discussed in this chapter is the importance of cocoa to the economy of Ghana. It discusses the trends in cocoa production and marketing.

Chapter Three deals with literature review. The review is divided into theoretical literature and empirical literature. Each section deals with levels of adoption, intensity of adoption and the impact of intensity of adoption on output. Chapter Four discusses the conceptual framework for the study. The research methodology for the study is treated in chapter five. Here a description of the study area is provided. Survey design and method for collecting data are described. Chapter Five also deals with the sampling techniques, sample size determination and method for analysing the results.

Chapter Six considers the determinants of adoption. Here the theoretical and empirical models are specified. The estimation of the empirical model and discussion of results are dealt with. Chapter Seven also discusses the models and results for intensity of adoption of cocoa research innovations. The impact of intensity of adoption of cocoa research innovations on output is treated in Chapter Eight. Chapter Nine dealt with the summary of the main findings, conclusions and recommendations based on outcome of the study. Also, the contribution of the thesis to knowledge, limitations of the study and suggestions for further study are treated in this chapter.

CHAPTER TWO

COCOA PRODUCTION IN GHANA

Introduction

This chapter deals with the history of cocoa production in Ghana. It begins with the origin of the word cocoa, varieties of cocoa, technical characteristics and history of commercial cultivation of cocoa in Ghana. It also considers the role of the Cocoa Research Institute of Ghana (CRIG) in the cocoa industry. The environmental conditions required for cocoa cultivation, areas under cultivation, method of cultivation and the various policy interventions in the cocoa sector are discussed in this chapter. Also discussed in this chapter are the trends in cocoa production and marketing.

Origin of cocoa

The name "cocoa" was derived from the word "cacao". The basic word 'cacao and chocolate' came directly from Mayan and Aztec languages (Awuah, 2002). The cocoa tree is a tropical plant grown in hot, rainy climates with cultivation concentrated on a narrow band of no more than 20 degrees north or south of the Equator.

The cocoa tree is believed to have originated from around the headwaters of the Amazon in South America. Its cultivation and value spread in ancient times throughout Central and Eastern Amazonian and northwards to Central America, particularly Mexico. The Olmec and Mayas were said to have considered it as 'food for the gods'. Cocoa beans were used by the Native Americans to prepare a chocolate drink or chocolate and also as a form of currency for trading purposes and payment of tribute to the king. It is believed that Christopher Columbus discovered cocoa beans in America but the beans did not become popular in Europe at the time. It was years later that Hernando Cortes discovered the bitter drink used by the Aztecs and sent the beans and recipes back to King Charles V of Spain in 1528. together with utensils for making the chocolate drink. The Spanish were said to have refined the recipes adding sugar and heating the ingredients to improve the taste. By 1580 the drink had been popularized in Spain and consignments of cocoa were regularly shipped to the country. The popularity of chocolate as a drink spread quickly throughout Europe, reaching Italy in 1606, France in 1615, Germany in 1641 and Great Britain in 1657 (UNCTAD, 1991).

Varieties of cocoa

According to Awuah (2002), Theobroma cacao belongs to the sterculiaceae family. There are three main types of cocoa namely: Criollo, Trinitario and Forastero. These groups can be distinguished by the structure of the fruit, the colour of the beans and the number of beans per cocoa pod. Criollo variety is presumed to have been grown by ancient Mesoamerican peoples. The fresh beans are thick, with a white or pinkish calyx, little astringency or bitterness, and after processing are very aromatic.

The Forastero variety derives from the sub-species, Theobroma Cacao Sphaerocavpum, and has fresh, flat purplish beans with a high astringency. There are two types – the upper Amazon and Lower Amazon variety known as

Amelonado which is most commonly grown in the world especially in Brazil and in West Africa. The Trinitario variety is a cross breed of the Criollo and Forastero. It combines some of the aromatic and sensory characteristics of Criollo with the robustness and high yield of the Forastero. In terms of quality. cocoa beans can be distinguished into aromatic cocoa (also known as fine, flavour or sweet) and non-aromatic or bulk cocoa. The first group includes Criollo, Trinitarion andNacional. The second group includes Forastero varieties.

Technical characteristics

The cocoa tree is usually about 4 to 8 metres tall, although when shaded by large forest it may reach up to 10 metres in height. The stem is straight, the wood is light in weight and the bark is thin, somewhat smooth and brownish. The fruit (pods) reach up to 15 – 25 cm in length. Each pod contains about 30 to 40 seeds which after fermentation and drying are known as cocoa beans (UNCTAD, 1991).

History of commercial cocoa cultivation in Ghana

Cocoa cultivation in Ghana has gone through a chequered history that dates back to the early 19th century during the era of the Dutch missionaries. Acquaah (1999) has catalogued the development of cocoa in Ghana and divided the period of introduction as the Missionaries Period 1857-1889, The Role of Tetteh Quarshie 1842 – 1892 and the Colonial Government.

Acquaah (1999) believed that some cocoa seedlings were brought into the then Gold Coast in 1801 by a Dutch missionary called Thonning and in

1815 by another Dutch missionary called de Goudkust, however the seedlings did not survive. Between 1807 and 1850, various Europeans and missionaries introduced many crops which might have included cocoa seedlings but since these seeds were planted in the dry coastal part in Gold Coast (now Ghana) it would be reasonable to assume that they did not survive due to the vagaries of the weather and lack of expertise in cocoa production.

The Period of the Missionaries 1857 – 1889

Acquaah (1999) believes that the Swiss were the first to bring cocoa to Gold Coast (now Ghana) and planted the first cocoa trees at an Evangelical Mission Society station at Akropong in the Eastern Region. This was one of the four missionary stations set up by the Basel missionaries who came to Gold Coast (now Ghana) in 1827. The missionaries tried to establish cocoa plantation at Akropong but the managers of the station lacked expertise and the trees suffered from pests and diseases and the project never succeeded.

In 1857 a Swiss agronomist Johannes Haas was appointed a manager of the Akropong Station. He imported cocoa seeds from Surinam, South America (on the Atlantic Coast). Unfortunately they were planted just before the Harmattan (dry) season and they did not germinate. Haas made another attempt in March 1858 but this was also not successful because the seeds had deteriorated during its six months storage (Acquaah, 1999).

In 1859 another Swiss agronomist, Johann Jakob Lang took over from Haas as manager of the Akropong station. Lang, with the help of Johann Gottlieb Auer, an ordained missionary at Akropong, brought some cocoa seeds from Cape Palmas off the West African coast and these formed the nucleus for an experimental nursery at Akropong. After three years, in February 1862, Lang recorded that he had raised ten little cocoa trees. However by January 1863 only two remained and in August the same year another died (Acquaah, 1999).

By October 1864, the only surviving tree had reached a height of five feet. Lang devoted all his attention on this little tree. Despite serious attack by ants about a dozen pods ripened and one year later Lang harvested them. Lang replanted some of the beans and the rest were sent to other evangelical stations at Aburi, Mampong and Odumase (Acquaah, 1999).

Lang transplanted ninety (90) seedlings from the nursery at Akropong to form the first cocoa plantation in Ghana. He had to return to Europe in June 1868 due to ill health but by that time he had also introduced coffee to Akropong and had increased the area of land under cultivation from 418 square metres to four acres. Lang's place was taken by a third Swiss farmer, Henri Marchand. In 1872, Marchand also had to leave Akropong because of ill health. His successors, Augusto Peteval and Hohann Jordi continued to develop the cocoa plantation until they returned to Europe in 1879 after which Ghanaians at the Mission took over the plantation (Acquaah, 1999).

The experiences and problems encountered by the missionaries at Akropong did not dampen the enthusiasm of other missionaries such as Arnold Mohr at Begoro. In 1889, Mohr imported some pods from the Cameroons but instead of attempting to raise seedlings himself, he took advice from a Basel missionary, Heinrich Behner who was in the Cameroons but had previously worked in the Akim areas in Ghana. Heinrich Behner was aware of the interest in cocoa that had been aroused in the local people who attended the mission churches in Akwapim, Akim and Krobo districts. It was to these farmers that Behner advised Mohr to distribute the cocoa seeds. They were given instructions on cultivation of the cocoa trees. However, the seeds could not thrive due to vagaries of the weather and lack of experience in the cultivation of cocoa (Acquaah, 1999). Even though the pioneering efforts of Haas, Lang and Marchand were not successful from productive point of view, it brought the attention of the Ghanaian to the crop.

Tetteh Quarshie (1842 – 1892)

According to Acquaah (1999), Sir Fredrick Gordon Guggisberg, one time Governor of the Gold Coast who did much to further the cocoa industry acknowledged Tetteh Quarshie to be the "Father of the cocoa industry in Ghana."

Tetteh Quarshie was born in 1842 at Christianborg in Accra to a farmer from Teshie called Mlekuboi. His mother was Ashong-Fio, a native of Labadi (now La). Tetteh Quarshie did not have formal education but was one of those who found favour with the Basel Missionaries at Christianborg and was accepted for training in their workshops as a blacksmith. Due to his hard work he became a master blacksmith after some years of apprenticeship and became the first blacksmith at the Akropong Experimental Farm at Mampong-Akwapim. He earned a good reputation in the community for his industry and integrity. In 1870, upon a request for artisans in Fernando Po (Bioko in Equatorial Guinea), Tetteh Quarshie travelled to the island. As a result of his previous interest in providing tools for cocoa cultivation, he worked on a plantation on contract-labour for six years, observing the intricacies of cocoa cultivation.

In 1876, Tetteh Quarshie returned from Fernando Po with five Amelonado cocoa pods which he planted both at Christianborg, Accra and Mampong-Akwapim where he had an offer of about an acre of land from Kwame Tuntum Adompore stool Land. The cocoa planted in Christianborg germinated but withered shortly afterwards owing to unsuitable soil and weather. Those planted at Mampong-Akwapim however grew well. It is believed that Tetteh Quarshie died on Christmas Day of 1892.

The Colonial Administration (1886 -1957)

Acquaah (1999) confirmed that successive colonial governments from Sir William Bradford Griffith in 1886 until independence in 1957 promoted the cocoa crop. It is however on record that it was Sir Fredrick Gordon Guggisberg who involved himself in the development of the cocoa industry. His strategies for the development of the cocoa industry were protection, improvement and development. In 1923 he passed the Plants (Injurious Pests) Ordinance despite opposition from elements in the Legislative Council. He brought in fourteen inspectors of plant to instruct and demonstrate to farmers the proper treatment of diseases and sanitation measures. He instituted a system in the buying centres so that beans could be graded by quality and higher price paid for better beans. Guggisberg believed that the future of the cocoa trade depended on good roads for motor transport to feed the railways, to feed the ports and a commodious harbour where ships could lie alongside the wharves in sheltered water. In this regard, Guggisberg constructed a number of roads, railway and the Takoradi Harbour. By the end of 1924, cocoa production in the Gold Coast (now Ghana) was at its peak of 223,000 tons making it the leading producer in the world (Acquaah, 1999).

The relatives of Tetteh Quarshie made a petition to the Gold Coast (now Ghana) Government on February 25, 1925 for a grant for the upkeep of some of Tetteh Quarshie's relatives. The then Ghanaian Vice-Principal of Achimota College, Dr. J.E.K. Aggrey strenuously took up the appeal. His friend, Sir Gordon Guggisberg set up the Tetteh Quarshie Memorial Scholarship at Achimota College. Other honours such as the Tetteh Quarshie House were bestowed on him. Another petition was made in 1927 and the Government gave a sum of two hundred and fifty pounds, although Nana Sir Ofori Atta, speaking in the Legislative Council asked for 2,500 pounds. Guggisberg completed his tenure as governor in 1927 (Acquaah, 1999).

Cocoa Research Institute of Ghana (CRIG)

According to Acquaah (1999) in September 1936, Opanin Yaw Sarbeng of Effiduase near Koforidua in the New Juabeng district of the Eastern Region of Ghana drew the attention of the Department of Agriculture to some unusual swellings of the young shoots and the defoliation of some of the cocoa branches on his farm which had resulted in the death of over 200 trees. Crops affected by the cocoa swollen shoot virus (CSSV) developed swollen or bloated appearance and eventually the tree would shed all off its leaves and die. Between 1936 and 1937, the colonial Department of Agriculture destroyed 81,000 cocoa trees on 300 farms. Nevertheless by 1938 the virus was widespread.

Establishment of CRIG

Acquaah (1999) intimates that to help curb CSSV, the colonial administration created the Central Cocoa Research Station in 1938 to investigate problems of disease and pests which had considerably reduced cocoa production in the Eastern Region. The proposed site at New Tafo about 40 kilometres from Koforidua was selected to accommodate various scientists. The station was established based on the advice of Sir Frank Stockdale, the then Agricultural Advisor to the Secretary of State of the British Colonies after his visit to West Africa in 1935. Sir Frank Stockdale recommended the establishment of a research station, which should determine the magnitude of the factors of production and device means by which the yield of existing farms might be maintained even if the rehabilitation of abandoned areas was not possible.

Based on the recommendation of Sir Fran Stockdale, the British Colonial government made funds available to meet the cost of establishing the research station. The Sierra Leone Government placed the services of their Mycologist, F. C. Deighton at the disposal of the Department. Central Cocoa Research Station and later, the Imperial Institute of Mycology arranged an inspection of the infected area by H. A. Dade, formerly of the Gold Coast Department of Agriculture. In 1939/40 cocoa crop season, the Botanist and Pathologist confirmed, through investigations at the Central Cocoa Research Station, Tafo that swollen shoot is transmissible by budding and grafting.

In 1943, Posnette, a plant pathologist of the Cocoa Research Institute, identified the unusual swellings on chupons and the discoloration of leaves of cocoa as disease. The disease spread very rapidly. On the New Juabeng strain of tree, the virus was observed to have increased three-fold in three years, eleven fold in five years and eighty fold in seven years (Acquaah, 1999). While further information was collected after the initial identification in 1943, the Department of Agriculture promoted a campaign for cutting-out the diseased trees before the infection could spread from them to other plots.

In 1944, the government of Gold coast (now Ghana). Nigeria, Sierra Leone and the United Kingdom set up the West African Cocoa Research Institute (WACRI), with its head quarters at Tafo. A sub-station was established at Moor Plantation in Ibadan in 1953. Since then Tafo has been the home of the Cocoa Research Institute and the focal point for the dissemination of knowledge about cocoa cultivation, disease and pests.

After the attainment of independence by Ghana and Nigeria, the inter-territorial basis of the Institute came to an end in 1962 and WACRI was accordingly dissolved. The Government of Ghana took over the station at Tafo and named it the Cocoa Research Institute of Ghana (CRIG). CRIG has since 1984 been a division of Ghana Cocoa Board.

Mandate

At its inception in June 1938, the Tafo Central Cocoa Research Station was assigned clear goals within the Gold Coast Department of Agriculture to investigate the pest and disease problems of cocoa in order to maintain production in the Eastern Region. In 1944 when the Research Station was upgraded to WACRI, the objectives were widened to include the disease and pest problems of cocoa in West Africa and also to investigate soil fertility and agricultural practices with a view to increasing yield. Since 1966 CRIG's research mandate has been further widened to include coffee, kola, sheanut and now cashew. CRIG conducts research into development of by-products of cocoa and the other mandated crops with the aim of diversifying utilization and to generate additional income for farmers.

Mission Statement

The mission of CRIG is to undertake research into all problems relating to production of cocoa, kola, coffee, sheanut and other indigenous and introduced tree species which produce fats similar to cocoa butter and to provide information and advice to policy makers on all related matters.

Objectives

The objectives of CRIG are to:

(i) provide farmers with husbandry practices/technologies for realizing optimal yields and high economic returns under environmental friendly conditions.

(ii) conduct research into and develop techniques for the processing of cocoa, coffee, sheanut and kola for the market.

(iii) conduct research into and develop new products (other than traditional ones) from cocoa, coffee, kola and sheanut with the aim of diversifying utilization and improving market prices and to develop by-products, and

(iv)establish strong linkage with Extension for effective transfer of research findings, new technologies and agronomic practices to farmers.

Achievements

CRIG has over the years gained reputation as a formidable research institute by International Standards and has long standing tradition of close collaboration with other international research Institutions. The Institute's research projects also receive international funding from organizations such as European Union (EU), CABI BioScience and others.

Control of Cocoa Swollen Shoot Virus Disease (CSSVD)

CRIG has successfully researched into characterization of the Cocoa Swollen Shoot disease as a virus disease and the discovery of mealy bugs as vectors of the disease in early 1940's. It also conducted further research into isolation and characterization of cocoa swollen shoot virus (CSSV) disease and development of diagnostic methods in the 1980's and 1990's. Since 1936, research work at CRIG has enabled it to declare CSSVD as one of the serious diseases with the cutting out of the affected trees as the main control measure. Research efforts have been focused on the strains, insect vectors, alternative hosts and control, use of barrier crops as a means of control. It is from the results of research work at CRIG, coupled with the serious nature of the disease that enabled Ghana Cocoa Board to set up CSSVD Control Unit with its Headquarters in Accra.

Major achievements in the CSSVD research at CRIG have been in the areas of epidemiology of the disease, the use of some economic crops as barrier for isolating replanted farms from the bordering and often infected cocoa trees; the use of mild strain cross-protection technique on the severer ones, and biochemical and molecular biological studies of the virus. Citrus and oil palm have been recommended as barrier crops in CSSV endemic areas.

Control of capsids by mass spraying with insecticides

Capsids are the most important pests of economic significance to cocoa in Ghana. The two main species responsible for crop losses are *Sahlbergella singularis* and *Distantiela theobroma.* These insects are capable of reducing yields of healthy farms to less than 25% of their potential in one year. Seedlings may completely fail to become established due to presence of capsids. Even when seedlings are not killed outright, capsids delay cocoa coming into bearing several years. On national scale, Owusu-Manu (1984) observed that about 25% of acreage under cocoa was badly affected by capsids causing annual losses of about 100, 000 tons of dry cocoa at the time. In the early 1950s CRIG identified the use of mass spraying with insecticides as the main antidote for capsids.

Understanding of cocoa fermentation and flavour chemistry

CRIG identified the right method of fermentation in the late 1950s. Once the cocoa beans are scooped from the pods, they should be fermented and dried in the two-step curing process that sets in motion the development of the flavour nuances which make the taste very nice. Fermentation is the first critical process to develop the beans' flavour. The beans, still covered with pulp, should be placed in large, shallow wooden boxes or left in piles and covered with banana leaves.

Once fermentation begins, the sugar in the pulp is converted into acids that change the chemical composition of the beans. Fermentation generates temperatures as high as 125 °F, activating enzymes that create the flavour precursors which are the beginning of chocolate as we know it. The fermentation process takes anywhere from two to eight days. (Unfermented or lightly fermented beans have less chocolate flavour but are higher in health-promoting antioxidants.

Shade management

Research at CRIG between 1959 and 1963 led to the understanding of the relationship between cocoa shade, nutrition and yield leading to agronomic packages giving yields of over 3 tons per hectare. Traditionally, cocoa is grown in Ghana in conjunction with a diverse selection of trees that provide shade and habitat for a variety of wildlife forms thus enhancing biodiversity. Anim-Kwapong and Frimpong (2004) carried out a study to examine the implications of growing cocoa under different shade regimes provided by forest trees and in full sun on litter fall, decomposition of the litter, soil fertility and cocoa pod development over one year period in Ghana. The study concluded that the level of overhead shade provided by forest trees in cocoa farms significantly influences litter fall, decomposition of the litter, soil fertility and development of cocoa pods. Under un-shaded farms, litter fall is very high but the rates of litter decomposition are very slow compared to the shaded farms.

Incidence of wilt is higher in un-shaded farms as a result of a likely higher moisture stress due to higher evapo-transpiration and the lower nutrient concentrations in the soils to support the higher crop yield. Shaded cocoa could therefore enhance efficient nutrient cycling processes, improve nutrient status of soils and promote healthy pod development.

Development of hybrid cocoa

In 1964, CRIG developed early bearing and high yielding cocoa varieties known as Series II hybrids by crosses between the Amelonado cocoa and the Amazon cocoa. The result of selective breeding work was the release of the Amazon types of cocoa in the 1950s and the "Tafo Hybrids" (Series II) in the 1960s. The CRIG breeders crossed Amelonado cocoa and local Trinitario types with new introductions from South America. The hybrids are vigorous, early bearing, precocious and high yielding. It was through the experiments conducted at the Institute during the early 1970s that hand pollination in the seed gardens was introduced. Strenuous efforts have been made by the Institute's breeders and pathologists to breed cocoa varieties which are resistant or tolerant to the Swollen shoot virus and black pod diseases and the Institute's scientists have come out with materials which are superior to the earlier hybrids (Series II) in yield and ease of establishment but have a higher level of tolerance. The materials also take shorter period to come into bearing. Currently there is a seed production Unit of the Ghana Cocoa Board which is responsible for the cocoa seed production for farmers in the country.

Pollination of clonal seed gardens for large scale production of seed pods

CRIG established bi-clonal or poly-clonal seed gardens in Ghana in the 1960s and 70s for large scale distribution of these hybrid varieties. Good quality hybrid seed can only be produced by hand-pollination as natural pollination results in large amounts of loss of yield potential and vigour. This finding became known only in the mid-1980s, at a time when large quantities of hybrid seed had already been distributed to the farmers.

Soil fertility management

One of the most important natural resources that cover much of the earth's surface is soil. Most life on earth depends upon the soil as a direct or indirect source of food. Plants are rooted in the soil and obtain nutrients from it. Animals also get nutrients from eating the plants on the soil. Soil is home of many organisms such as seeds, spores, insects, and worms. The contents of soil change constantly and there are many different kinds of soil. It forms very slowly and is destroyed easily, so it must be conserved in order to continue to support life.

According to Appiah et al (1997), the continuous mining of inherent fertility of cocoa soils without replenishment has been identified as major cause of the low productivity of cocoa farms. Results of experimental trials on farmers' farms by Cocoa Research Institute of Ghana (CRIG) indicated that low soil fertility is a major cause of the decline in yields. However, fertilizer application increased yields from 250kg per hectare to 1,500 kg per hectare after the 4^{th} year of fertilizer application (Ghana Cocoa Board, 2002). The recommendation of the Cocoa Research Institute of Ghana (CRIG, 1987) is that fertilizers should be applied once a year at the beginning of the rains (April-May).

Cocoa high technology programme

The cocoa high technology package was developed by CRIG to assist farmers increase and maintain productivity through soil fertility maintenance. The "High Technology" of cocoa production is defined as the sustainable cocoa production by which the farmer increases and maintains productivity through soil fertility maintenance at levels that are economically viable, ecologically sound and culturally acceptable using efficient management resources (Appiah, 2004).

As a prelude to the more elaborate main project, a pilot project which involved the application of fertilizer to farms covering an area of 40,000 hectares began in March-April, 2003 in selected districts of all the main cocoa growing regions. Each selected farmer was assisted to apply the technology to 0.8 hectares (2 acres).

Before the implementation of the main project which started in 2004/05, CRIG trained all stakeholders on various aspects of the project. Series of meetings/workshops/farmers rallies at District level were organized by CRIG to sensitise all stakeholders on their respective roles. Training programmes on proper agronomic practices which had to be adopted before and during the project were organized for farmers and extension staff of Ministry of Food and Agriculture (MOFA). Demonstrations on fertilizer application were held for the farmers and extension agents.

Two main types of fertilizer formulations are used in the Hi-Tech Programme. These are granular fertilizers (for example Asaasewura and Cocofeed) and liquid fertilizers (with examples as Sidalco Balanced and

Sidalco Potassium Rich). These fertilizers are supplied by traditional suppliers and have been tested and approved to be used on cocoa by CRIG.

Development of cocoa by-product

According to Appiah (2004) and CRIG (2010), CRIG took the first step in the 1960s to initiate research into cocoa by-products by setting up a committee of experts with representation from the universities of Ghana to identify by-products that could be produced from cocoa pods and cocoa beans. The aim was to maximise the farmer's income from cocoa cultivation.

Currently, by-products produced from cocoa are Cocoa jam/marmalade, Cocoa wine, Cocoa gin and Cocoa brandy. Others are Cocoa soft soap popularly known as "Alata Samina", Cocoa butter soap and Cocoa body pomade also produced from discarded cocoa beans. Animal feed is also produced from cocoa pod husk.

Environmental conditions needed for the cultivation of cocoa in Ghana

Cocoa requires certain environmental and climatic conditions for them to thrive very well. These conditions include soil, rainfall and temperature.

Nature of soils

Cocoa needs deep well-drained soils, adequately supplied with nutrients and moisture and containing little or no coarse material (Dickson and Benneh 1988). Following Adu and Mensah-Ansah's (1969) classification of soils in Ghana, Ahenkorah (1981) categorized soils in Ghana into cocoa suitability soils based on textural and depth analyses.

The model profile of good cocoa soils are deep and characterized by well drained non-gravelly top soil over sandy clay loam layer which usually contains both iron oxide concretions and quartz gravels. This layer overlies sedentary mottled clay, which merges with the incompletely weathered parent material. The unsuitable soils are highly desaturated ferrallitic soils, primarily tropudults and paleudults (Forest Oxysols and Oxysol-Ochrosol intergrade). These soils cover the South of the Western region. It is on these soils that the moves to extend the area planted in recent years have taken place. Without fertilizer application, their lack of available minerals results in limited yields and to premature tree aging.

The suitable soils are moderately desaturated ferrallitic soils (dystropepts / Forest Ochrosols). These are primarily found in the old cocoa growing areas of Eastern and Ashanti regions. It is possible, without fertilizer application and with light permanent shading to achieve potential yields of around 1500 kg per hectare over fifteen years or so. The highly suitable soils are only slightly desaturated ferrallitic soils (tropical eutrophic brown soils/ Forest Ochrosol-Rubrisol intergrade) with a high exchange capacity-hence a better response to mineral fertilizers. These are generally well-drained and deep soils occurring in limited areas in Ashanti and in the North of Western region.

Rainfall

For ideal production, cocoa trees need rainfall between 1,150 and 2,500 mm per year (UNCTAD, 1991). Studies have shown that cocoa is highly susceptible to drought and the pattern of cropping of cocoa is related to rainfall distribution. Significant correlations between cocoa yield and rainfall over varying intervals prior to harvest have been reported. It was found that in Ghana a year with high rainfall is followed by a year with a large crop, though the correlation was not applicable in all years (Smellie, 1925; Skidmore, 1929, Brew, 1991). Ali (1969) reported both positive and negative correlations between rainfalls in certain months with the yield of the main crop in Ghana.

The annual total rainfall in the cocoa growing regions of Ghana is below 3000 mm. There are two rainfall seasons which are April to July and September to November. There is a short dry period from July to August during which the relative humidity is still high with over cast weather conditions. There is a main dry season from November to February-March. The four to six months of dry weather results in soil water deficit and since irrigation is not part of the farming system, cocoa seedling mortality is high during the establishment phase. In bearing plants, the existence of the short dry season during main crop pod filling can affect bean size if it is sufficiently severe. In adult plantings, water deficits result in lower yields and an increase in the level of mirid damage.

In considering the suitability of a soil for cocoa in relation to soil moisture, it is not the quantity of available soil moisture *per se* which is important; it is rather the rate of release of the available water from the soil to the tree which matters (Wessel, 1971; Ahenkorah, 1981).

Temperature

Cocoa tree requires temperature between 21 ^{0}C and 32 ^{0}C (UNCTAD, 1991). Cocoa as a tropical crop can only be profitably grown under temperatures varying between 30-32 °C mean maximum and 18-21 °C mean minimum and absolute minimum of 10 °C (Wood & Lass, 1985). Temperature has been related to light use efficiency with temperatures below 24 °C having a decreasing effect on the light saturated photosynthesis rate (Hutcheon, 1977). Temperatures below 10 °C caused severe inhibition of the photosynthesis rate. The stomata of chilled leaves never opened as wide as stomata of non-chilled plants. Leaf temperature affects stomata resistance, decreasing the resistance upon increasing temperatures. However, since the increases in temperature may often go together with higher vapour pressure deficits (VPD), the effect of VPD may override the effect of temperature (Raja Harun & Hardwick, 1986).

In Ghana, the period of high temperatures when the widest range in the maximum and minimum temperature occurs have been noted to coincide with flushing (Hurd & Cunningham, 1961; Asomaning, Kwakwa & Hutcheon, 1971).

Areas under cocoa cultivation in Ghana

In Ghana cocoa is grown in forest areas of Ashanti, Brong Ahafo, Eastern, Volta, Central and Western regions where rainfall is between 1,100 and 3,000 mm per annum. Extremely wet and swampy lands are not suitable. The soil should be permeable and at least 1.2 metres deep. Cocoa should not be planted in rocky places. Figure 1 is the map of Ghana showing the cocoa growing regions.

Method of cultivation

Cocoa farmers may start a new farm or replant an old farm or maintain an existing farm. Starting a new farm involves the clearing of a virgin land suitable for cocoa production. Farmers may also replant cocoa in old and denuded farms. Farmers may also maintain an existing farm which is doing very well. Whether the farmer starts a new farm or replants an old farm, once the cocoa is established the cultural maintenance of weed control, pest and disease control, shade management, fertilizer application, among others is the same. The economic life span of the cocoa tree is not known; but under the best conditions of soil and management, it can be kept in bearing almost indefinitely.

Amoah (1995) divided the commercial cocoa production into the following five main stages: establishment, maintenance of mature farms, harvesting, fermentation and drying and sale of dried beans. These stages are explained in details.

Establishment of cocoa farm

Cocoa production in Ghana is highly labour intensive. It begins with land preparation for establishing the cocoa farm. Land preparation involves tree felling, slashing of the vegetative cover, burning of the bush and clearing of the debris. All these activities are performed by men. Cocoa beans may be sowed directly or planted as seedlings, which may be purchased or nursed by the farmer. The young cocoa plants are interspersed with food crops to provide shade for the plants and food for the farmer during the formative years of the farm.

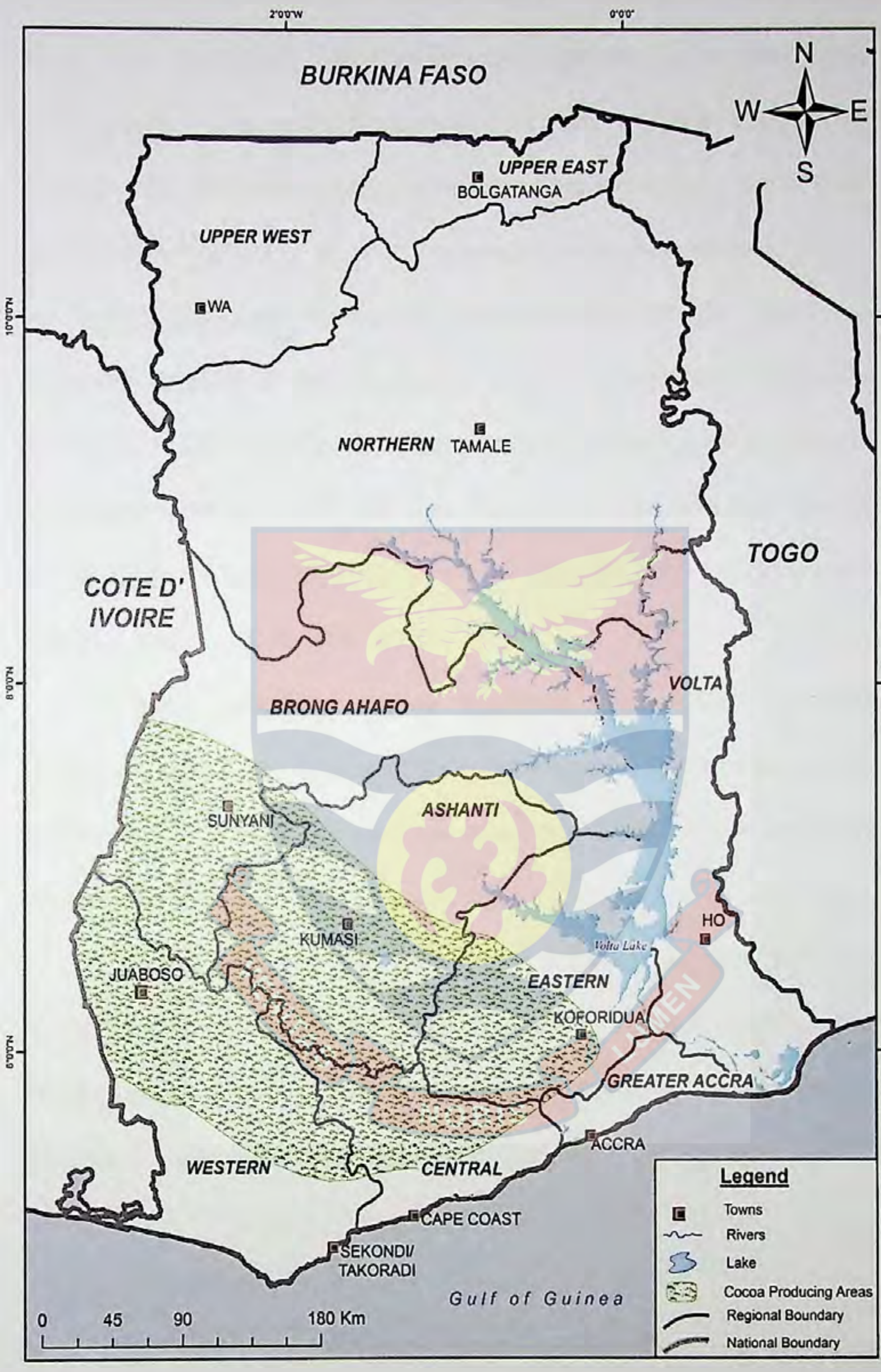

Figure 1: Map of Ghana showing cocoa growing areas

Before the cocoa trees form a canopy, weeding is carried out about three times in a year. Weeding is very important in the early years of development of cocoa. The frequency of weeding will depend on the rate of weed growth. Weeding reduces competition between young cocoa trees and weeds for soil nutrients. Regular weeding of farms therefore tends to protect the young plants from weeds and promote healthy growth. Weeds can be controlled manually with a machete (cutlass) or chemically with herbicides. Manual weeding should be done 3 to 4 times in a year for young cocoa farms. Herbicides such as Glyphosate may be used to control weeds. For young cocoa, 1.5 to 2 Litres of Glyphosate in 100 Litres of water per hectare may be applied (Amoah, 1995; CRIG, 2010).

Young plants may require protection from attacks by pests and diseases by spraying with recommended insecticides. The farm is sprayed with insecticide about four times in a year to control capsids which can attack the cocoa trees.

Shade plants need to be pruned to give enough sunlight. The extent of the pruning tends to be related to the cocoa plants' natural growth of canopy. At this stage of pruning, special care must be taken to get the right pattern for the future development of the tree and the canopy.

Maintenance of mature farms

The establishment stage of cocoa production may last approximately four years if good early bearing seeds are used. At the end of the establishment process the cocoa trees will have begun to produce pods, thereby paving the way for a process which is essentially that of maintaining the farms to attain maximum yield. The farm maintenance activities include weed control, pest and disease control, shade management, fertilizer application and pollination. Weed control in mature farms is similar to weed control of young farms under establishment stage. The only difference is that, as the cocoa matures and it canopy becomes complete the rate of weed growth is slowed down permitting a reduction in the level of weed control. Weeds may be controlled manually by weeding about twice a year. Weeds can also be controlled chemically by application of 1 Litre of Glyphosate in 100 Litres of water applied about two times in a year (CRIG, 2010).

Cocoa pests such as mirids (capsids) stem borers, mealy bugs and termites can be controlled by application of insecticides such as Bifenthrin (Akate master), Thiomethoxam (Actara) and Imidacloprid (confidor). The swollen shoot disease is controlled by cutting down the infected trees and their neighbouring ones. Continuous cropping results in reduction in soil fertility. Application of fertilizer provides nourishment to the plants. To arrive at fertilizer recommendations, one needs information on nutrient supply in the soil, leaf analysis, existing shade management situation, appropriate fertilizer to be used and the testing of the said recommended fertilizer under local average farm conditions. There two main types of fertilizer namely organic and inorganic fertilizer. Organic fertilizers are derived from plants and animals. Some examples are poultry manure, compost and cocoa pod husk ash. Inorganic fertilizers are made from non-living substances such as gases, rocks and industrial chemical.

Three types of fertilizers are recommended by COCOBOD namely conventional (inorganic) fertilizers, foliar/liquid fertilizers and organic fertilizers. Conventional (inorganic) fertilizers are applied to the soil either by broadcasting or ringing under cocoa trees once a year. Fertilizer application can be carried out on the same plot for four consecutive years with 1 or 2 years break. Foliar/liquid fertilizers usually contain minor nutrients such as magnesium, zinc and boron that are required in small quantities and sometimes some in addition to major plant nutrients, such as nitrogen and potassium. Foliar fertilizers are usually applied when there is lack of soil moisture and solid fertilizers cannot be applied. The recommended types are Sidalco liquid fertilizers. It is recommended to apply foliar/liquid fertilizers at monthly intervals.

Pollination is done to improve yield. Inadequate pollination will lead to diminishing yield. The pollen transfer may be inadequate if insufficient number of flowers are pollinated or if each flower received less than the minimum amount of pollen required to fertilize the ovules for the setting of the lower. The experience with hand pollination in several cocoa growing countries has shown that the necessary skills can be acquired within a short period of training. However, to achieve the best results, the farmer must have manual dexterity and good eye sight (Amoah, 1995).

Harvesting

Development of the pod takes 5 – 6 months from fertilization of the flower to full ripeness for harvesting. Harvesting of cocoa consists of three sub-processes namely: pod plucking, pod opening, and transporting of beans for fermentation. Pod plucking entails removal of the ripe pods from the cocoa tree. Pods are normally removed by using various forms of knives or cutlasses or hooks. The usual practice for opening of pods is to gather the pods to one or more convenient places in the farm before the opening exercise begins. Pods are opened using a cutlass or machete, club or by hitting them against a stone or stick. When pods are opened, the beans are removed for fermentation. Beans are joined to a placenta in the pod. The said placenta must be separated from the wet beans preferably before fermentation. If the placenta is not removed before fermentation it can lead to a high incidence of double and multiple beans in the dried product.

Some farmers transport pods to areas designated for fermentation before opening. Others open the pods and transport the wet beans to the appropriate places for fermentation (Amoah, 1995).

Fermentation

Fermentation begins the same day the pods are broken. Raw cocoa has an astringent and unpleasant flavour and must be processed after harvest into good-tasting and good flavour chocolate. The importance of cocoa fermentation is to develop chocolate precursors in the bean. The cocoa bean itself does not undergo fermentation but the pulp surrounding it. The pulp is an undamaged pod microbial sterile. However, it gets contaminated during pod breaking with microorganisms from the surrounding environment including pod surfaces, knives and workers' hands. Fermentation is normally done in six days and it is caused by microbial succession. Micro-organisms involved in fermentation are yeasts, lactic acid bacteria and acetobacter (CRIG, 2010).

There are four methods of fermentation. They are heap, basket, box and tray methods but the most commonly used are heap, basket and box methods. Heap fermentation is the simplest and is normally used on small farms. It is done by spreading out fresh plantain leaves in a circle on the ground and heaping fresh cocoa beans on them. The mat of leaves should be punctured with a pointed stick to create drainage holes in the mat. This allows easy pulp drainage. The heap beans is then covered with more leaves and held in place by small logs. Covering protects the fermenting beans from surface drying, mould growth and helps to maintain the heat generated within the heap.

Basket fermentation is usually used on small-holder farms. There is no definite size for the baskets. The baskets are first lined with fresh plantain leaves before placing the wet beans in them. They are covered with more leaves which are held in place with small logs. The sweating drain from the sides and the bottom of the baskets and air also passes through the sides and the bottom. The fermenting mass is turned by transferring the beans from one basket to the other.

Box fermentation is done in large perforated boxes made of local hardwood. The holes at the bottom of the boxes allow the sweating from the pulp to drain down and air to enter. Therefore they are always raised above the ground level and placed over a drain. The boxes are normally raised in tiers so that turning is done by removing beans from a higher box into a lower one. The beans are placed in the top box and covered with a few layers of plantain leaves. This method reduces labour in turning the beans.

To facilitate uniform fermentation in the above methods, the beans are turned after 48 hours with a second turning done after another 48 hours. Fermentation is allowed to continue for another 48 hours or until temperature begins to fall and the odour of ammonia develops, when fermentation can be considered to have been completed. Fermentation usually lasts between 5 and 7 days (CRIG, 2010).

Drying of cocoa

At the end of fermentation, drying begins. It is done the same day fermentation ends. Drying is the reduction of the moisture content in fermented beans from about 55% to 7%. After fermentation, the beans are carried to the drying area and spread thinly on raised mats. These mats ensure uniform drying. Drying should not be done on the bare floor or asphalt roads. The beans must be stirred frequently to pick out germinated, flat and black beans, placenta and any foreign materials. There are two methods of drying which are sun drying and mechanical drying. Mechanical drying is generally not recommended because it is expensive; there is danger of smoke contamination and high acid retention in the beans (CRIG, 2010).

Storage of cocoa beans

After drying the cocoa beans are cleaned of any extraneous matter and packed into clean, strong jute bags. The great care to achieve optimum quality from harvest to drying must continue during storage. The dry beans are stored in a well ventilated storage room with relatively low humidity to avoid re-humidification of the beans. The bags of cocoa must be packed on wooden pallets to avoid rodents and insect pests. Storage must also not be in close proximity with any strong odours. Fire should not be made in the room where cocoa is stacked. Forced air, fumigation and good sanitary practices all contribute towards optimal storage conditions (CRIG, 2010).

Labour requirement and sources in cocoa production in Ghana

According to the Ministry of Manpower Youth and Employment (MMYE, 2007) the farmer's household is the main source of labour for the cocoa farm, contributing almost 60 percent of the total labour requirement. Table 3 shows the sources of cocoa farm labour.

Table 3: Sources of cocoa farm labour

Category	Percent Contribution
Farmer's own labour	30.0
Spouse (s)	15.2
Hired Labour	27.4
Communal Labour (Nnoboa)	6.5
Others	20.7

Source: MMYE (2007). *Labour Practices in Cocoa Production in Ghana (Pilot Survey)*, Accra: Ministry of Manpower Youth and Employment. Page 26.

Matured and adult labourers are required to undertake all the cocoa production processes. Even though the farm owners contribute their own labour, hired labourers are often used to provide some of these services. The hired labourers may either be caretakers, daily wage earners or contract workers (MMYE, 2007). Table 4 shows the number of man days required to undertake the various activities on the cocoa farm.

Table 4: Activity man days per hectare

Activity	Man Days	Remarks
Land clearing	20-25	Depends on the nature of bush.
Felling and chopping	15-20	Depends on the nature of trees felled.
Stumping and debris gathering	15-20	Depends on the state of cleared area.
Holing for suckers	5	
Planting of suckers	10	
Holing for seedlings	5	
Planting of seeds/seedlings	10	
Brushing	15-20	
Capsid control	2	with 1 for water carrying
Black pod control	5	with 2 for water carrying but depends on farm performance.
Mistletoe Control	4	
Fertilizer application	4	
Plucking of Pods	5	But depends on the farm performance
Gathering and heaping of pods	4	But depends on farm performance
Breaking of pods	6	But depends on the farm performance
Carting of fermented beans	4	But depends on the farm performance
Drying of beans	3	But depends on the farm performance
Carting of dried beans	4	But depends on the farm performance

Source: Research Department, COCOBOD, Accra

The labour required for any particular activity by any farmer depends on some important factors. For instance, the land to be cleared for cocoa farm establishment may either be a virgin forest, which will be more involving and so demand more man-days compared to a secondary forest. In the case of virgin forest there will be more trees which need to be cleared and this will require more man hours. On the other hand if the land involves secondary forests they may contain few or no big trees to be felled and in effect require even less man-days.

Also, the number of labourers required to harvest, gather and heap as well as break pods from a hectare of cocoa farm is largely dependent on the performance of the farm. If yield is high, the labour requirement is correspondingly high and vice versa (MMYE, 2007).

Baah (2006), following FAO/World Bank (1986) identified five distinct production technologies used in cocoa production as indicated below.

Technology level 1

Under this technology, the farmers prepare the land by first slashing, felling of trees and burning of the bush at the onset of the dry season. The farmers then plant food crops such as cocoyam, plantain and cassava. Cocoa is inter-planted at stake at irregular spacing with unselected seed from the farmers' own farm (or those of neighbours) at high density with 2,500 or plants per hectare. The farmers do little brushing, no pruning and infrequent removal of mistletoes. They often do not protect the cocoa against capsids or black pod (by spraying with pesticides) or undertake shade control. Consequently, mean yields are in the region of 200 to 225 Kg per hectare.

Technology level 2

Under this technology, the farmers perform all the activities described under Technology Level1 except that farmers use hybrid seeds resulting in slightly higher mean yields of between 300 and 325 kilograms per hectare.

Technology level 3

Farmers in this category also use unselected seeds and plant at stake randomly resulting in high density. They brush farms twice instead of recommended thrice or four times per annum. They however do regular pruning, mistletoe removal and shade control. They also protect the cocoa pods from capsids attack by spraying the farm 2 to 3 times a year with capsicides, and spraying against black pod with fungicides when severe. These practices result in the relatively higher mean yield of about 400 kilogram per hectare.

Technology level 4

Farmers in this category perform activities as those in technology level 3 except that they use hybrid seedlings raised in polybags and well spaced at 2.5 by 2.5 metres. Mean yields are in the region of 550 kilogram per hectare.

Technology level 5

Farmers who apply the full complement of CRIG recommendations belong to technology level 5. The farming practices are as described for farmers in technology level 4 except that farmers here manipulate the shade regime of the cocoa trees by planting shade trees such as Glyricidia spp. They also apply chemical or organic fertilizer carry out routine pesticide spraying against capsids and black pod, and control rodents' attack on the pods. Mean yields of dry cocoa beans are in the region of 700 kilogram per hectare.

According to Asante (1994) and CRIG (2010), researchers at CRIG have divided the technologies into three technology levels namely: low (levels 1 and 2 above combined), medium (levels three and four above combined) and high (level five).

CRIG (2010) estimated cost of cocoa production per hectare under different technologies namely low production technology level, medium production technology level and high production technology level. Typical costs of establishment of one hectare of cocoa in Ghana as at June 2010 were:

i. Low production technology level – GHC609.50

ii. Medium production technology level – GHC1,229.50

iii. High production technology level – GHC1,279.50

For matured farms cost of production one hectare as were as follow:

i. Low production technology level – GHC1,500.00

ii. Medium production technology level – GHC1,211.09

iii. High production technology level – GHC813.20

The high technology level gave the least average cost and thus ideal technological level for profit maximisation. Information on the cost do not only help to compare total cost with total revenue for different technology levels but even different components within the same technology and identifying which components contribute more to cost and/or revenue and then finding out how to reduce cost and enhance revenue.

The cost components included in the computation were:

1. Size of land which is usually estimated as rent per annum. Sometimes it is necessary to divide cost of acquisition by the period of the lease to get the cost/rent per annum.
2. Land preparation which involves clearing, stumping, etc
3. Planting which may include planting materials, nursery development, cost of planting itself and transportation.
4. Weeding which is either manual or chemical
5. Fertilizer application which also includes cost, transport and application cost.
6. Application of insecticides/fungicides which may include cost of chemical, cost of spraying (may include hiring of sprayer).
7. Harvesting which involves plucking, gathering of pods, breaking of pods, fermentation, among others.
8. Transportation of produce to point of sale.

It is worth noting that most labour operation may be in the form of contract by-day charges and it may be necessary to estimate opportunity cost of family labour or any other inputs at the prevailing market price in the area.

Trends of cocoa output in Ghana

Since the introduction of cocoa in Ghana in the late 19th century, the crop has undergone a series of major expansions and contractions. Ruf and Siswoputranto (1995) suggest that cycles are intrinsic to cocoa production because cocoa is influenced by environmental factors such as availability of forest land; ecological factors such as deforestation, outbreaks of disease, and geographic shifts in production; and economic and social factors such as migration.

Ruf and Siswoputranto (1995) identified four distinct phases with regard to cocoa production in Ghana. These phases are: introduction and exponential growth (1888–1937); stagnation followed by a brief but rapid growth following the country's independence (1938–64); near collapse (1965–82); and recovery and expansion, starting with the introduction of the Economic Recovery Program (1983 to present).

Figure 2 shows trends in cocoa production from 1969/70 to 2009/10 seasons. Growth in cocoa production became more pronounced starting in 2001, possibly driven by a combination of record-high world prices, increased share being passed onto farmers, and a set of interventions such as mass spraying and hitech programme rolled out by the Cocobod (Vigneri & Santos, 2008).

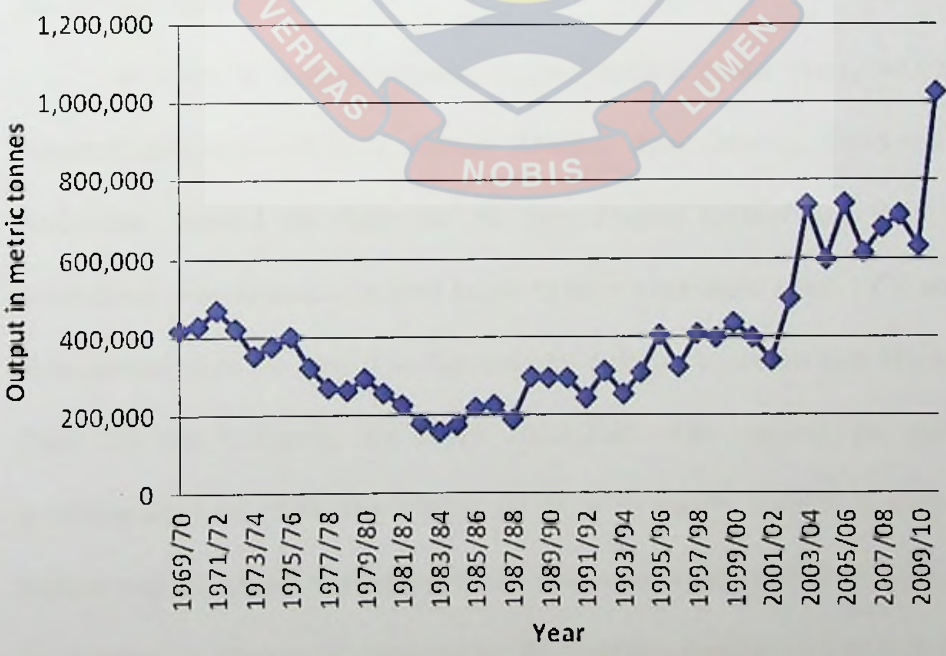

Figure 2: Trends in cocoa production

Some of the growth during this period may also have been due to the influx of cocoa smuggled from Côte d'Ivoire, estimated between 120,000 and 150,000 tons in 2003/4 (Brooks, Croppenstedt & Aggrey-Fynn, 2007). Trends of output of cocoa according to the Regions are presented in Appendix A.

Cocoa policy interventions

Policies and interventions to boost cocoa production have always been in the areas of diseases and pests control, farm rehabilitation, producer price management, produce payment processes, soil fertility management, planting materials, and research and extension services.

By 1930, after Ghana had been the leading producer of cocoa for about 20 years, cocoa production in the Eastern Region was plagued with pests and diseases, which caused production to fast decline. The situation called for policy interventions that could control the problems and arrest the declining production trends.

In 1936, a strange disease, cocoa swollen shoot virus, which was detected and reported by a farmer, Opanin Yaw Sabeng, Effiduase near Koforidua, formed the basis for the first disease control policy in cocoa production. The disease was later learnt to have been there since 1920 and had even spread over the area. The Agricultural Adviser to the British Minister of State for the Colonies, Sir Frank Stockdale, who studied the problem, recommended in 1935, the setting up of a Research Station at Tafo. The station was mandated to investigate the disease and pest problems of cocoa in the country in order to recommend the best control measures so as to maintain production levels. Based on the recommendations of the Research Station, the policy of cutting out diseased cocoa trees was enacted. This policy intervention mandated the Agricultural Workers to cut out all affected trees since the causal agent was identified to be a virus.

The Cocoa Swollen Shoot Virus Disease Control Unit, a division of COCOBOD, has been entrusted with the mandate to cut out all identified diseased trees and their contacts after which treatment/ex-gratia grant is paid to the farmer. Hybrid seed planting materials are then supplied to the farmer for replanting of the treated area, which then paves the way for the payment of first and second replanting grants.

The cocoa black pod disease also poses a big threat to cocoa production in Ghana. The incidence was reported to be very high in the Ashanti and Brong Ahafo Regions in the early 1980s. Crop losses were estimated to be between 50 percent and 100 percent. The Research Station at Tafo, now Cocoa Research Institute of Ghana (CRIG), identified the causal agent to be Phytophthora megakarya and recommended the use of fungicides in spraying the cocoa farms as a means of control. Due to the intensity of the disease, a programme of mass spraying dubbed "*Ye Wafuo Yie*" (maintain your farm properly) was introduced by COCOBOD in 1986 to encourage the effective and efficient application of recommended farm practices alongside fungicidal spraying to achieve improved yields.

In order to sustain the interest of farmers and as a sequel to this initial programme, the "*si anonom kwan preko*" (prevent the incidence of black pod disease) was again put in place and made competitive in 1988. Disease and pest problems continue to plague the cocoa industry and to efficiently manage these problems, the Government through the Ghana Cocoa Board, has since the 2001/02 cocoa season, been organising a nation-wide cocoa diseases and pests control programme (mass spraying) free of charge for the farmers.

Control of capsids was also started in 1944 using 1 percent aqueous DDT suspension, which had been screened and recommended by the Research Station. Capsids are sucking insects and they damage the soft, young tissues of the tree by piercing the young shoots with their mouth, injecting poisonous saliva and then sucking liquid food out of the wound. These wounds become infected with a fungus leading to death of the affected shoot. A large scale capsid control programme (dubbed mass spraying) was organised in 1956, using Gammalin 20 (lindane) when the effects of capsid damage on the cocoa farms became very devastating. Cocoa production in 1956 stood about 220,819 and was about one third of production in the world (Amoah, 1998). The capsid control programme resulted in high increases in cocoa yields and Ghana's production of 580,000 mt in 1964/65 was attributed largely to the 'saturation spraying' campaign in the early 1960's. The current policy intervention in a form of "mass spraying programme" is seen as a replication of the spraying policy of the 1960s. Apart from swollen shoot and capsid control programmes, Government instituted other interventions in the form of bilateral aid projects aimed at sustaining cocoa production.

These were dubbed "Cocoa Rehabilitation projects I, II and III". The first two projects, which covered the Suhum area in the Eastern Region (Suhum Cocoa Project) and parts of the Ashanti Region (Ashanti Cocoa Project), were carried out from 1970 to 1979. The main aim of the projects was to replant and rehabilitate all dead and abandoned cocoa farms in the two regions for the farmers, the cost of which were to be defrayed from proceeds from the farms when the farmers started harvesting. The areas that were rehabilitated under the projects are now the heaviest production centres in the regions, especially in the Eastern Region.

After a series of studies by the Cocoa Research Institute of Ghana, it was realised that the low land productivity being experienced in the cocoa farms were as a result of soil mining from continuous harvesting of pods. To turn around the declining trends in land productivity, therefore, the fertiliser application programme, dubbed "Cocoa High-tech" was introduced in the 2002/03 crop year after a series of on farm trials. This programme encourages cocoa farmers to apply fertilisers to a minimum of two bags per acre of their matured cocoa farms for a start, to help improve the performance of the farm. The fertilisers under these programmes were supplied on credit to the beneficiary cocoa farmers in the initial stages. Payments were to be made during the ensuing harvesting season by instalments. Unfortunately, this policy intervention though has enjoyed maximum participation from the farmers, is bedevilled with high indebtedness from the beneficiary farmers. The programme has now been repackaged and only farmers in a cooperative society or an association can benefit from the credit distribution after payment of an initial deposit. This programme had positive impact on national cocoa production and resulted in output of 736,975 tons and 740,458 tons during the 2003/04 and 2005/06 cocoa seasons, respectively.

Another key intervention is the supply of planting materials to cocoa farmers, which has gone through a series of developmental stages, dating back from the first introduction of cocoa beans into Ghana. The cocoa varieties supplied to farmers as planting materials started from the old type brought in by Tetteh Quarshie, which is Amelonado. This was supplemented with the Amazonian type of cocoa from Trinidad. Through scientific research, a new variety, hybrid, was developed from a cross between the Amelonado and Amazonian. Currently, the policy is to gradually phase out all the old Amelonado and Amazon varieties and to replace them with the high yielding and early bearing hybrid variety of cocoa. The hybrid has been found to be very prolific and to produce all year round if only favourable weather conditions are experienced. Thus, it has the potential to help increase national output.

Furthermore, the government has been reviewing the producer price paid to farmers to encourage them to increase output. The producer price was raised from ¢85,000 per mt to ¢150,000 in 1988 at the onset of the third Cocoa Rehabilitation Project which was 65 per cent of FOB. The policy was again reviewed in 1999, and the producer price was projected to be raised gradually to reach 70 percent of fob price by the 2004/05 cocoa season (Ghana Cocoa Board, 1999). As at October 2012, the producer price was GHC3, 392.00 per tonne which was 78.36 per cent of FOB price (MOF, 2013). The policy of the government has been to pass on significant share of export prices to the farmers. The annual increases of the producer price have resulted in the retrieval and rehabilitation of abandoned farms, expansion of old farms, and the establishment of new ones. All these are contributory factors to the increasing trends of cocoa production witnessed in the country, especially in the past four years.

Payment for farmers' produce has since the establishment of the cocoa industry, been by cash at the farm gate. According to Sowa (1999) until August 1979, the payment for cocoa purchases by purchasing clerks from farmers was made mostly by cash. The cash was obtained either from the buying agent's own finances or from bank loans. The system of cash purchases coupled with the buying agents system posed several problems for the cocoa industry. Some farmers took advances against future delivery of cocoa from one buying agent and sold the actual produce to another. Some farmers had to mortgage or sell their farms to pay off debts. The cash system of payment was also beset with other problems such as long delays before payment; fraudulent practices, for example paying clerks investing cash meant for produce purchases in other ventures and paying farmers after the maturity of their investments and security problems of moving cash over long distances.

Partly in a bid to eliminate these problems and partly to inculcate banking habit into the cocoa farming communities, a new system of payment known as "Akuafo Cheque" system was introduced in 1979 on a small scale. This system involved the issue of payment vouchers to farmers which they could then cash at commercial or rural banks. The Akuafo cheque system was reorganised in 1983 and made the only system for payment of cocoa farmers. The introduction of the Akuafo system was an improvement over the cash system, it also faced some problems. Some of the problems associated with the system were: inadequacy of banking outlets for administration of the cheques; inadequate stocks of cash at some bank branches at certain peak demand periods; discontinuation of banking services by the farmers after the close of the cocoa season and the issue of fraudulent cheques (Sowa, 1999).

As part of efforts to arrest the decline in cocoa production, the Government of Ghana, through Cocoa Board, introduced a National Cocoa Diseases and Pest Control (CODAPEC) programme, popularly known as "Mass Spraying" in the 2001/02 cocoa season to assist all cocoa farmers in the country to combat the Capsid/Mirid and the Black Pod disease. Other objectives were to train farmers and technical personnel on the cultural and chemical methods of pests and diseases control, educate and train local sprayers on safe pesticides usage, help put more money in the pockets of farmers and create jobs for the unemployed youth in the rural communities.

Conclusion

This chapter dealt with the history of cocoa in Ghana. Even though the missionaries were the first to make attempt to introduce the crop to Ghana, it was Tetteh Quarshie who brought cocoa from Fernando Po and successfully cultivated the crop at Mampong Akwapim. The Cocoa Research Institute of Ghana (CRIG) was established to research into problems facing the cocoa industry. CRIG has achieved a number of successes and these include control of swollen shoot disease; control of capsids by mass spraying with insecticides; shade management; understanding fermentation; development of hybrid cocoa; mass hand pollination and introduction of the cocoa high technology programme.

The chapter also dealt with the various policy interventions to boost cocoa production. The interventions included disease and pest control

(CODAPEC), labour survey in cocoa production, cocoa rehabilitation projects, and cocoa hi-tech programme. The importance of cocoa to the economy of Ghana include contribution to the GDP, employment generation, development of infrastructure such as roads and hospitals, contribution to central government revenue, source of foreign exchange, scholarships to farmers' children, expansion of banking facilities and forward and backward linkages to other sectors of the economy. In the next chapter a review of the related literature is provided.

CHAPTER THREE

REVIEW OF RELATED LITERATURE

Introduction

This chapter deals with a review of related literature on determinants of technology adoption, intensity of technology adoption and the impact of adoption on output. The purpose of the literature review is to determine the existing frontier of knowledge on the topic. The review considers both theoretical and empirical literature on the topic. It begins with the theoretical literature which considers the theory behind adoption decisions and impact of technology adoption on output. This is followed by the empirical literature which deals with studies on level of adoption and intensity of adoption in Ghana and other countries. The empirical literature also considers studies on the impact of technology adoption on output. The chapter concludes with a summary of the main themes contained in the review.

Theoretical Literature

The theoretical literature review considers theories used to explain determinants of adoption and intensity of adoption and the impact of adoption on output. Thus, the review is structured under the three main themes of the thesis. The theories underpinning technology adoption and the theory of production have been explained.

Determinants of technology adoption

A number of theories have been propounded to explain technology adoption. These include the theory of reasoned action. theory of planned behaviour, unified theory of acceptance and use of technology, diffusion innovation theory and technology-organisation-environment framework. Others are rational expectation theory of technology adoption and agricultural household models.

Theory of reasoned action

The theory of reasoned action (TORA) was propounded by Ajzen and Fishbein (1980). According to the theory, a person's behavioural intention depends on the person's attitude about the behaviour and subjective norms. Three main components of TORA are behavioural intention (BI), attitude (A) and subjective norm (SN). Behavioural intention is a function of both attitudes toward a behaviour and subjective norm toward that behaviour. Attitude consists of beliefs about the consequences of performing the behaviour multiplied by his or her evaluation of these consequences. Subjective norm is seen as a combination of perceived expectations from relevant individuals or groups along with intentions to comply with these expectations.

The theory explains that a person's behavioural intention depends on the person's attitude about the behaviour and subjective norms. The theory is one of the "expectancy-value" models of human behaviour and its terminology is not very different from that of the well-established subjective expected utility model used by economists (Lynne, 1995). The theory postulates that a person's intention to perform (or not perform) a behaviour is the immediate determinant of that action, barring unforeseen events; people are expected to act according to their intentions (Ajzen, 1988). A person's intention to behave in a certain way is based on their attitude toward the behaviour in question, and their perception of the social pressures on them to behave in this way, that is subjective norms. The relative contribution of attitudes and subjective norms varies according to the behaviour context and the individual involved. Attitudes are determined by the beliefs of the outcomes of performing the behaviour and the evaluation of the expected outcomes. The subjective norm is dependent on beliefs about how others feel the individual should behave and their motivation to comply with these others (Ajzen & Fishbein, 1980). Thus, a farmer may adopt a technology based on his behavioural intention which is dependent on his attitude and subjective norms.

The theory of reasoned action has been criticised by Werner (2004) for neglecting the importance of social factors that in real life could be determinants for individual behaviour.

Technology acceptance model

Technology acceptance model (TAM) was originally proposed by Davis (1986). It is an extension of the theory of reasoned action by Ajzen and Fishbein (1980). The technology acceptance model has been used to explain why users accept or reject a particular technology. According to the technology acceptance model, one's use of a technology depends directly or indirectly on the user's behavioural intention, attitude, perceived usefulness of the technology, and perceived ease of the technology. The theory also proposes that external factors affect intention and actual use of the technology.

The technology acceptance model has been criticised to have limited explanatory and predictive power, questionable heuristic value, triviality and lack of any practical value (Chuttur, 2009). The technology acceptance model has also been criticised by Benbasat and Barki (2007) that it focuses on the individual user and ignores the essentially social process of technology development and implementation.

Theory of planned behaviour

The theory of planned behaviour (TPB) was introduced by Ajzen (1988). The theory of planned behaviour states that attitude alone is not sufficient to predict behaviour, but that social pressures and the perceived difficulty in carrying out the action are also important. Theory of planned behaviour regards beliefs as fundamental blocks of behavioural intention. Three different types of beliefs namely behavioural belief, normative belief and control beliefs are distinguished. These beliefs are considered indirect influence on behavioural intention. Intention itself is mediated through the direct intent factors; attitudes, subjective norms and perceived behavioural control, aggregation of different beliefs.

According to Taylor and Todd (1995), a person's actual behaviour in performing certain action is directly influenced by his or her behavioural intention and in turn jointly determined by attitude, subjective norm and perceived behavioural control toward performing the behaviour. Behavioural intention is a measure of strength of one's willingness to try and exert while performing certain behaviour. Thus, the difference between the theory of planned behaviour and theory of reasoned action is its addition of the component of perceived behaviour. According to the theory of planned behaviour, perceived behavioural control together with behavioural intention can be used directly to predict behavioural achievement. Ajzen (2001) considers other factors that might be assumed important to the formation of intentions, such as demographic characteristics and prior experience to be already incorporated into theory of planned behaviour. To the extent that a person has the required opportunities and resources, and intends to perform the behaviour, he or she should succeed in doing so. The limitation of the theory of planned behaviour is that it overlooks emotional variables such as threat, fear, mood and negative or positive feeling and assessed them in a limited fashion.

Diffusion of innovations theory

The diffusion innovation theory (DOI) seeks to explain how, why and at what rate new ideas and technology spread through cultures operating at the individual and firm level. According to Rogers (1995), the theory sees innovation as being communicated through certain channels over time within a particular social system. Individuals are seen as possessing different degrees of willingness to adopt innovations, and thus, it is generally observed that the portion of population adopting an innovation is approximately normally distributed over time. Breaking this normal distribution into segments leads to the segregation of individuals into the following categories of individual innovativeness (from earliest to latest): innovators, early adopters, early majority, late majority and laggards. The early adopters, as the name implies, are the first people to use the innovation. The early adopter has the highest degree of opinion leadership in most systems and they usually constitute about 13.5 percent of the social system. Early adopters are expected to be younger, more educated, venturesome and willing to take risk. The early majority, who usually form about 34 percent of a social system, adopt new ideas just before the average member of a system. The late majority may be considered as sceptical and adopt new ideas after the average member of a system have adopted. The late majority usually constitute about 34 percent of the social system. Laggards are the last in a social system to adopt an innovation and they constitute about 16 percent. Late adopters are expected to be older less educated, conservative and not willing to take risks.

Rogers (1995) continues that innovation process in organisations is much complex. It generally involves a number of individuals, perhaps including both supporters and opponents of the new idea. Based on the diffusion of innovation model, at the firm level innovativeness is related to such independent variables as individual (leader) characteristics, internal organisational characteristics and external characteristics of the organisation.

According to Rogers (1995) technology adoption follows a sigmoid (S –shape) curve. When a technology is first released only a few agents adopt it. Then later more agents adopt, increasing the rate of adoption. With time the number of potential adopters decreases, causing the rate of adoption to decrease. Eventually an adoption ceiling is reached before all agents have adopted. For those who choose not to adopt, the technology may not be profitable, it may not be feasible, or an even newer technology may have been adopted instead. The S-shape has been explained using three main approaches namely epidemic, Bayesian learning and game theory.

Rogers (1995) has placed the contributions and criticisms of diffusion research into four categories namely pro-innovation bias, individual-blame bias, recall problem and issues of equality. The diffusion innovation model has been criticised that technologies are not static as the theory believes. There is continual innovation in order to attract new adopters all along the S- shaped curve. The S-shape curve does not just happen; instead the s-curve is made up of a series of "bell curves" of different sections of the population adopting different versions of a generic innovation.

Technology, organisation and environment framework

The technology, organisation and environment framework (TOE) was developed by Tornatzky and Fleischer (1990). The TOE framework is an organisation level theory that explains that three different elements of a firm's context influence adoption decisions. These three elements are: technological context (current practices and equipment internal to the firm), organisational context (descriptive measures of the organisation such as scope, size and managerial structure) and environment context (its industry, competitors and dealings with the government). The framework is consistent with the diffusion of innovation (DOI) theory in which Rogers (1995) emphasized individual characteristics and both the internal and external characteristics of the organization as drivers of organisational innovativeness. These are identical to the technology and organisation context of the TOE framework, but TOE framework also includes new and important component, environment context. It is the environment context which distinguishes the TOE from the DOI.

Rational expectation theory of technology adoption

The rational expectation hypothesis (REH) is attributed to Muth (1961). The essence of the rational expectations hypothesis is that economic agents form their expectations on the basis of the "true" structural models of the economy in which they make decisions. So, their expectations are essentially the same as predictions of the relevant economic theory: their expectations are informed predictions of the future.

The REH suggests that people are able to learn fast to adapt to changes in economic conditions and to anticipate what will happen in the economic system by examining the patterns of economic activity. The REH effectively maintains that every individual acts as an economic forecaster using the information he or she can collect to foretell what economic events are likely to happen. The forecasts are the individual's rational expectation. The basic assumption of the theory is that people use all of the information available to them efficiently. However, even though rational expectation may not be accurate, at least they will be unbiased. The rational expectation theory of adoption suggests that under certain conditions, we can expect to observe clustered adoption defined as the adoption of technology by multiple firms about the same time.

REH's strong assumptions fail to consider that people have bounded rationality so although all information are available to them, they may not be able to process the information quickly and accurately. Sargent (1993) proposed instead the theory of adaptive learning to relax some of the strong assumptions. In adaptive learning, people are allowed some time to learn about the economic circumstance and update their expectations about relevant parameter values on the basis of newly received information.

Unified theory of acceptance and use of technology

The unified theory of acceptance and use of technology (UTAUT) model was formulated by Venkatesh, Morris, Davis and Davis (2003) to explain user intentions to use an information system and subsequent usage behaviour. The purpose of the UTAUT model is to offer the manager with using tools to weigh the introduction of new technology and predict and explain the user's behaviour of accepting a technology. The theory holds that the determinants of usage and intention are performance expectancy, effort expectancy, social influence and facilitating conditions. Gender, age, experience and voluntariness of use are considered to have impact on the four key determinants of intention and behaviour. The theory was developed through a review and consolidation of a number of models which existed before its introduction. These theories included theory of reasoned action, technology acceptance model, motivational model, theory of planned behaviour, model of computer use, diffusion of innovations theory and social cognitive theory.

The UTAUT and its subsequent extensions have been criticised by Baggozzi (2007) as being chaotic because of the eight (8) dependent variables and forty-one (41) independent variables involved. He proposed instead a unified theory that coheres the "many splinters of knowledge" to explain decision making. The UTAUT model has also been criticised by van Raaij and Schepers (2008) as being less parsimonious than the previous technology acceptance model because its high coefficient of determination (R^2) is only achieved when moderating key relationships with up to four variables.

Agricultural household models

Agricultural household models are a staple of micro research on less developed countries. Originally envisioned as a tool for price policy analysis, household-farm modelling techniques have been used in a number of researches ranging from technology adoption and migration to deforestation and biodiversity.

Agricultural technology adoption is best explained using utility maximization approach under agricultural household models. According to Taylor and Adelman (2002), the household's objective is to maximize a discounted future stream of expected utility from a list of consumption goods, subject to some constraints including family time and endowments of fixed productive assets, cash income, and prices (of inputs, outputs and non-produced consumption goods). Prices are exogenously determined and where there are missing markets, shadow prices are used. The solution of a household model yields a set of core equations for outputs, inputs demands, consumption demands and profit. Thus the solution of farm household model represents all dependent or exogenous variables as a function of exogenous variables (which include prices of tradables, farm assets, household time constraint and other household characteristics).

In their review of many adoption studies, Feder, Just and Zilberman (1985) observed that the land a farmer can operate each period is given and, thus, he maximizes his expected utility subject to land availability.

Imperfections in the credit and labour markets may also result in credit and labour constraints that affect the farmer's choice. The solution to the temporal optimization problem at the beginning of each period determines the type of technology the farmer will use in the period, his allocation of land among crops, and his use of variable inputs. At the end of each period, the actual yields, revenues and profits are realized; and this added information, as well as the parameters the farmer will use in his decision making in the next period.

In the formulation of Singh, Squire and Strauss (1986), the household for any production cycle is assumed to maximize a utility function. Assuming U is the Utility function for a household, X_a, X_m and X_l are agricultural staple, market purchased good and leisure, respectively; P_a and P_m are the prices of X_a and X_m respectively, Q_a is the household output of X_a; P_l is the market wage; L is total labour input; F is family labour which implies that L-F is positive; it is hired labour but if it is negative it is off farm ; V is a variable input such as agricultural technology and its price P_v; E is non-farm income; T is total time available; A and K are household's fixed quantities of land and capital stock respectively. The relationship is expressed as follow.

$$U = U(X_a, X_m, X_l) \qquad \text{Utility function} \qquad \ldots 1$$

The utility function is maximized subject to the following constraints:

$$P_m X_m = P_a(Q_a - X_a) - P_L(L - F) - P_v V + E \qquad \text{Cash Constraint} \qquad \ldots 2$$

$$X_l + F = T \qquad \text{Time Constraint} \qquad \ldots 3$$

$$Q_a = Q(L, V, A, K) \qquad \text{Production Constraint} \qquad \ldots 4$$

The three constraints were collapsed into one by substituting the production constraint into the cash constraint for Q_a and substituting the time constraint into the cash constraint for F as:

$$P_m X_m + P_a X_a + P_l X_l = P_l T + \pi + E \qquad \text{... 5}$$

Where $\pi = P_a Q_a(L, V, A, K) - P_l L - P_v V$ ... 6

Maximization of the household utility subject to the single constraint yields the following:

$P_a \dfrac{\partial Q_a}{\partial L} = P_l$ Demand equation for labour ...7

$P_a \dfrac{\partial Q_a}{\partial V} = P_v$ Demand equation for input (say fertilizer for technology)...8

$\dfrac{\partial U}{\partial Xa} / \dfrac{\partial U}{\partial X_m} = \dfrac{P_a}{P_m}$ Demand for agricultural staple/manufactured good ... 9

$\dfrac{\partial U}{\partial X_l} / \dfrac{\partial U}{\partial X_m} = \dfrac{P_l}{P_m}$ Demand for leisure ... 10

Since our interest is technology adoption (V), we make V the subject of the function as in equation 11.

$$V = f(P_a, P_v, P_m, P_l, X_m, X_l, X_a, K, A, L, F, T, \mu) \qquad \text{... 11}$$

A number of studies on adoption behaviour have pointed out that a host of explanatory factors influence adoption behaviour of farmers. For instance Langyintuo and Mekuria (2005) identified factors such as farm size, membership of farmers' association, leadership position in the community, access to credit, information, and availability of output and input market as important determinants of technology adoption. Also, the review of adoption studies by Feder et al (1985) indicated that adoption decisions are influenced by a number of socioeconomic, demographic, ecological and institutional factors and are dependent on the nature of the technology. The impact of these variables on adoption decisions are explained under the respective headings.

Age of the farmer

The role of a farmer's age in explaining technology adoption is somewhat controversial in the literature. Older people are sometimes thought to be less amenable to change and hence reluctant to change their old ways of doing things. In this case, Ervin (1982) and Norris and Battie (1987) believe that age will have a negative impact on adoption. On the other hand, older people may have higher accumulated capital, more contacts with extension, better preferred by credit institutions, larger family sizes, etc all of which may make them more prepared to adopt a technology than younger ones. In that case age will have a positive relationship with adoption.

Education

Langyintuo and Mekuria (2005) believe that it is assumed that educated farmers are better able to process information and search for appropriate technologies to alleviate their production constraints. The belief is that education gives farmers the ability to perceive, interpret and respond to the information much faster than their counterparts without education.

Farm size

According to Feder et al (1985), the size of the farm is a factor that is often argued as important in affecting adoption decisions. Farm size can have different effects on the rate of adoption depending on the characteristics of the technology and institutional setting. More specifically, the relationship of farm size to adoption depends on such factors as fixed adoption costs, risk preferences, human capital, credit constraints, labour requirements, tenure arrangement and so on. It is frequently argued that farmers with larger farms are more likely to adopt an improved technology compared with those with small farms as they can afford to devote part of their fields to try the improved technology. It is also known in the literature that lumpy technologies such as mechanized equipments that require economies of size for it to ensure profitability, there is often minimum threshold farm size for adoption (e.g. animal traction). But in general the directional effect of farm size on adoption is contradictory.

Labour availability

Availability of household labour is an important variable which in most cases has an effect on household's decision to adopt new technologies. Feder et al (1985) opine that some new technologies are relatively labour saving, and others are labour using. For example ox cultivation technology is labour saving, and its adoption might be encouraged by labour shortage. On the other hand high yielding varieties (HYV) technology generally requires more labour inputs, so labour shortages may prevent adoption.

The supply of labour in the rural areas may be the farmers own labour, labour from farmers children (i.e. Family size) and other dependants who may be members of the extended family, hired labour and non-hired labour such as reciprocal labour. The labour available to the farmer will therefore depend on the household size made up of the farmer's children and the number of dependants; hired labour and non-hired labour,

Membership of association

Feder et al (1985) observed that in most farming communities, farmers form or join associations or cooperatives of various kinds for all sorts of reasons. Such associations or cooperatives sometimes afford farmers the opportunity to have better access to information, which is an important condition for adopting an improved technology. Some financial institutions are prepared to lend credit to farmers only when they are in an association or cooperative. Therefore belonging to an association or cooperative can influence farmers' decision to adopt improved technology.

Frequency of extension advice

According to Feder et al (1985), extension officers provide information on farming practices to farmers. Exposure to information reduces subjective uncertainty and therefore increases the likelihood of adoption of new technologies.

Credit access

Feder et al (1985) argued that lack of credit is a constraint to adoption. This is often the case for lumpy technologies (e.g. mechanical technologies) in particular although improved adoption may require credit to procure complementary inputs to maximize their benefits. Farmers can invest in new technologies either from past accumulated capital or through borrowing from capital markets. The lack of sufficient accumulated savings by smallholder farmers prevents them from having the necessary capital for investing in new technologies. Also, capital market failure exists in most developing countries due to lack of information on interest rates and alternative credit sources.

Determinants of intensity of adoption

The theories used to explain intensity of technology adoption are the same as those which are used to explain the determinants of adoption. The reasoning is that one will have to decide to use a technology before he or she intensifies its usage. We however, provide a review of how the diffusion innovation theory is used to explain determinants of intensity of adoption in this section.

Under the diffusion of innovation theory, Rogers (2003) explained rate of adoption as the relative speed with which an innovation is adopted by members of a social system. The determinants of rate of adoption of innovations are presented in figure 3. The variables that determine the rate of adoption of innovation are perceived attributes of innovation; types of innovation decision; communication channels; nature of social system and extent of change agent's promotion efforts.

The perceived attributes of an innovation are important explanation of the rate of adoption of an innovation. According to Rogers (2003), most of the variance in the rate of adoption of an innovation, from 49 to 87 percent, is explained by five attributes namely relative advantage, compatibility, complexity, triability and observability.

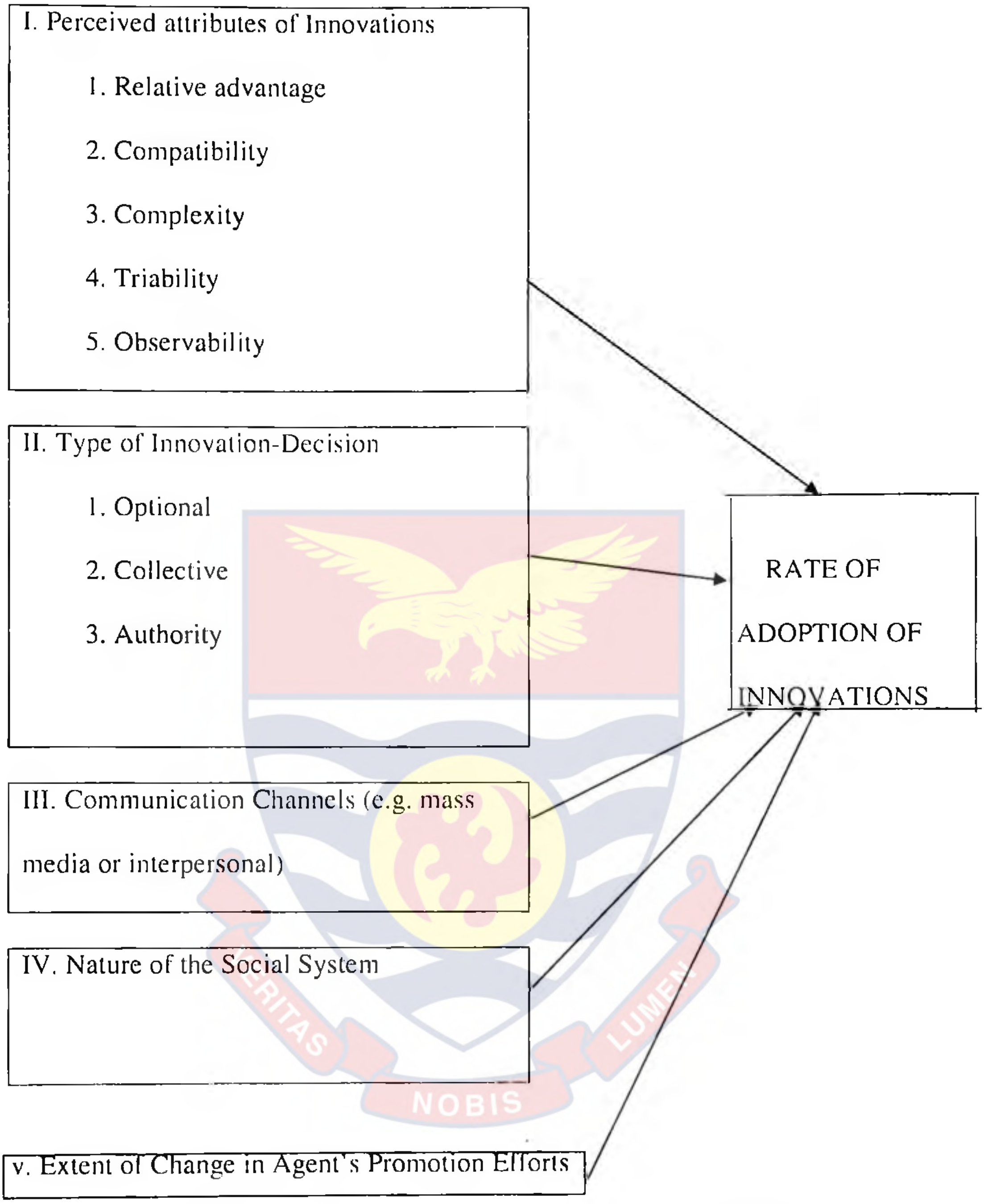

Figure 3: Variables Determining the Rate of Adoption of Innovations

Source: Rogers E. M. (2003), Diffusion of Innovations, p 222

Explaining the type of decision, Rogers (2003) indicated that innovations requiring an individual-optional innovation-decision are generally adopted more rapidly than when an innovation is adopted by an organization. The more the persons involved in making an innovation decision, the slower the rate of adoption.

Rogers (2003) further explained that the communication channels used to diffuse an innovation also may influence the innovation's rate of adoption. For example, if interpersonal channels (rather than mass media channels) create awareness-knowledge, as often happen for later adopters, the rate of adoption is slowed. The nature of a social system such as its norms, and the degree to which the communication network structure is highly interconnected, also affect an innovation's rate of adoption. An innovation's rate of adoption is also affected by the extent of change agents' promotion efforts. The relationship between the rate of adoption and change agents' efforts, however, may not be direct and linear. A greater payoff from a given amount of change agent activity occurs at certain stages in an innovation's diffusion. The greatest response to change agent effort occurs when opinion leaders adopt, which usually occurs at somewhere between 3 and 16 percent adoption in most systems. The innovation will continue to spread with little promotional effort by change agents, after a critical mass of adopters is reached.

Impact of adoption on output

In production theory, factors of production are combined to produce a given output. Production is the process by which factor inputs are transformed into output. An increase in the quantity of factor input, will other things equal, lead to an increase in output. The theory of production is the study of how output level changes as the quantity of factor inputs change. Solow (1967) believes that the pure theory of production is fundamentally microeconomic in character; it deals with physically identifiable inputs and outputs.

According to Green (2008), the economic concept of production generalizes from a simple well-defined engineering relationship to higher levels of aggregation such as farms, plants, firms, industries or for some purposes, whole economies that engage in the process of transforming labour and capital into gross domestic product by some ill-defined production process. The economic theory of production is based on production frontiers and value duals such as cost, revenue and profit frontiers, and envelope properties yielding cost minimising input demands, revenue maximising output supplies and profit maximisation output supplies and input demands. Emphasis is placed on optimising behaviour subject to constraint.

The adoption of new technologies designed to enhance farm output and income has received particular attention as a means to accelerate economic development (Schultz, 1964; Kuznets, 1966; Hayami & Ruttan, 1985). However, output growth is not determined by technological innovations but also by the efficiency with which available technologies are used (Nishimizu & Page 1982).

According to Varian (1999), the set of all combinations of inputs and output that comprise a technologically feasible way to produce is called a production set. The function describing the boundary of this set is known as the production function and it measures the maximum possible output that can be obtained from a given amount of input. The production function could be expressed in different functional forms such as Cobb-Douglas, linear, quadratic, polynomial and square root polynomials, semi log and exponential function. However, the Cobb-Douglas function is commonly used for its simplicity and flexibility coupled with the empirical support it has received for various industries.

Using two inputs, the production function $f(x_1, x_2)$ would measure the maximum amount of output y that could be obtained if we had x_1 units of factor 1 and x_2 units of factor 2. In the two input case the convenient way to depict production relations is known as the isoquant. An isoquant is the set of all possible combination of inputs 1 and 2 that are just sufficient to produce a given set of output. Two examples of technologies are the Cobb-Douglas and fixed proportion or Leontief technology. Assuming parameters such that $0 < a<1$, the Cobb-Douglas production function can be defined as in equation 12.

$$f(x_1, x_2) = x_1^{a} x_2^{a-1} \quad \text{.... (12)}$$

The isoquant for a Cobb-Douglas production function is convex to the origin and the slope defines the degree of substitutability of the factors of production. Using parameters a >0 and b<0, equation 13 defines the Leontief technology.

$$f(x_1, x_2) = \min(ax_1, bx_2) \quad \text{... (13)}$$

The isoquants for Leontief technology is shown in Figure 4. In figure 4, the X axis measures input for technology X_2 whilst the Y axis measures input for technology X_1. The isoquant is L shaped implying that increasing only one input will not result in higher output.

According to Koutsoyiannis (2002) as knowledge of new and more efficient methods of production become available, technology changes. Furthermore new inventions may result in the increase of the efficiency of all methods of production. At the same time, some techniques may become inefficient and drop out from the production function. These changes in technology constitute technological progress.

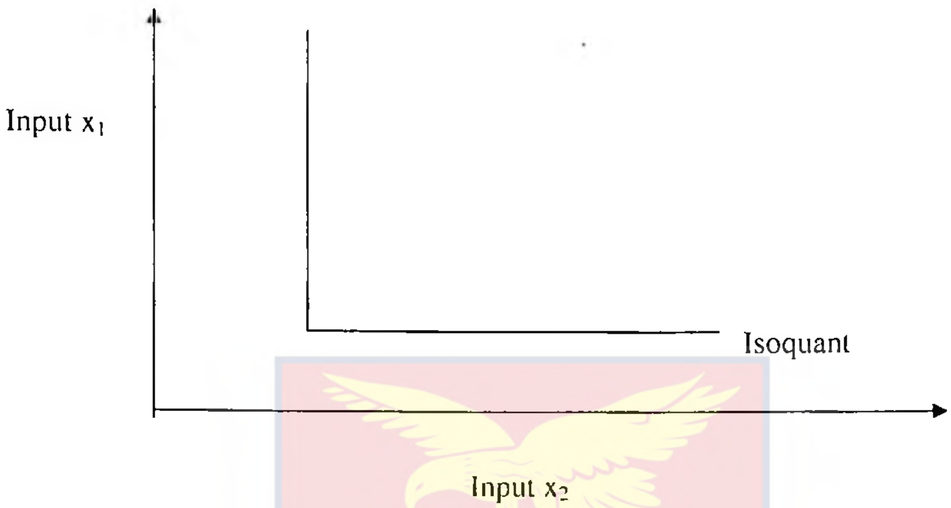

Figure 4: Fixed proportions or Leontief technology

Koutsoyiannis (2002) explains that adoption of improved technology will lead to an increase in output, other things being equal. Graphically the effect of innovation on output is shown as an upward shift of the production function or a downward movement of the production isoquant. This shift shows that the same output may be produced by less factor inputs or the same output may be produced by less inputs or more output may be obtained by the same inputs.

There are several ways of measuring productivity and technical efficiency. Koopmans (1951) defined technical efficiency as the capability of a firm to maximize output for given inputs. This definition however, does not offer any guidance concerning the degree of inefficiency. This issue was addressed by Farrell (1957). He extended the work initiated by Koopmans and suggested measuring inefficiency as the observed deviation from a factor isoquant. Farrell (1957) proposed to measure technical inefficiency as one minus the equiproportionate reduction in all inputs for given outputs. A score of unity indicates technical efficiency because no equiproportionate input reduction is feasible, and a score less than unity measures severity of technical inefficiency.

Green (2003) defines technical efficiency as the relationship between observed production and some ideal or potential production. In the case of a single output, we can think in terms of output to the optimal values as specified by a production function.

Factor-augmenting technical change

Adoption of improved technology will result in a technical change and increase in output, other things being equal. According to Solow (1967), the general way to represent technology in a single product function is:

$$Q = F(X, Y; T) \qquad \dots (14)$$

Where Q is output, X and Y are inputs (all measured in natural physical units) and T is a parameter or even, for extra generality, a vector of parameter, each value of which corresponds to a different level of technology. It is natural to think of T changing in time, perhaps smoothly as knowledge accumulates: in that case F should be a non-decreasing function of T. However, T may change from place to place or from time to time. In principle the production function corresponding to two different Ts can be any two production functions. If we assume constant returns to scale in X and Y, so that everything is summed up in the unit isoquant, then corresponding to T1 and T2 may be any pair of isoquants for Q=1. If the change from T1 and T2 is intended to be unambiguous technical progress, then the only restriction is that the later isoquant should never pass outside of the earlier. If in fact the shift from T1 to T2 has occurred continuously, then any continuous deformation of the first isoquant to the second is a possible path provided only that movement is always inward. In that case the production function depicting augmenting technical change becomes:

$$Q = F[a(T)X, b(T)Y] \quad ... (15)$$

An improvement in a specific input say X may be reflected in a or b or both. There are other forms measurements of technical progress such as induced bias in technical progress by Kaldor's (1957) technical progress function.

Empirical literature review

In line with the three themes of the study, the empirical literature review has also been divided into three namely: determinants of technology adoption, determinants of intensity of adoption, and the impact of adoption on output.

Determinants of technology adoption

According to Feder et al (1985), models for explaining level of adoption may be static or dynamic. A static model refers to a farmer's decision to adopt an improved technology at a specific place and a specific period of time. This model attempts to answer the question of what determines the pattern of adoption at a particular point in time. Logit or probit models are employed. In these models the adoption decision is merely whether or not to adopt where a functional relationship between the probability of adoption and a set of explanatory variables is estimated econometrically using logistic distribution for the logit procedure and the normal distribution for the probit procedures. It is worth noting that the logit/probit methods investigate the effects of regressors on the choice to use, but it does not measure the degree or intensity of adoption. One limitation of the static model is that it does not account for time in the adoption process for farmers' ability to learn to improve their technical efficiency in growing and marketing the crop. The weaknesses identified in the static models are addressed in the dynamic models proposed by Ghadim and Pannell (1999). In a dynamic model, at the beginning of each period the type of technology the farmer uses in that period, his allocation of land to different crops and use of other variables are determined. At the end of each period, the actual yields, revenues and profits/losses realized, information and experiences accumulated during the period by the farmer and information from other farmers are used to update decision making in the next period.

Basely and Case (1993) have written extensively on modelling technology adoption in developing countries. They believe a lot of knowledge about the adoption of new technology comes from time-series evidence. In these data one observes only aggregate measure of adoption, such as the percentage of farmers employing the new technology at each date. The purpose is to capture the shape of the time-series diffusion process, and these studies tend to model the pattern of adoption as a logistic – shaped function over time. They explained that letting P_{it} represent the fraction of adopters in *i* region at date *t*, one can estimate using equation 16.

$$P_{it} = f(P_{it-1}) + \varepsilon_i \quad \ldots (16)$$

Even though it may be possible to divide the function to capture regional characteristics, the main purpose in such studies is often to estimate the inter-temporal component of the relationship. While disaggregating by region and investigating the effect of regional characteristics on adoption give some insight into what might drive adoption, this approach is limited in what it can say about the underlying dynamic process.

Basely and Case (1993) further explained that cross sectional data are of two kinds. First are studies that take a snapshot of M farmers' technology at some date. The gain to farmer *i* of using the new technology is parameterized as $\gamma X_i + \mu_i$ where X_i are farm and farmer characteristics and μ_i is an independently and identically distributed farm specific ex ante shock. It is often assumed that the shocks are normally distributed and the model is then run as a probit using equation 17.

$$\Pr o(adoptionbyfarmeri) = \Phi(\gamma X_i / \sigma_\mu) \quad \ldots\ldots (17)$$

Where Φ (.) is the distribution function of the standard normal. The purpose of this research is to measure the impact of X_i on adoption. Some cross sectional surveys contain information based on recall about when a farmer adopted a technology. Creating for each farmer a set of discrete choice observation equal to *1* if farmer *i* was using the technology at time *t*, *t* Є (1 ... T) and zero, otherwise a probit can be estimated using equation 18.

$$\Pr ob\{d_{it} = 1\} = \Phi(\gamma X_i + \rho T + [Tx\, X_i]) / \sigma_\mu \quad \ldots. (18)$$

Where T is time representing a set of $\tau - 1$ year indicators and T x X_i are interaction terms that allow the influence of field and farm characteristics to change over the diffusion process. Basely and Case (1993) further indicated that a researcher can use panel data to overcome limitation of time series and cross sectional data and that Heckman (1981) offers an excellent survey of methods for handling such models. However, the availability of panel data forces researchers to think harder about reasonable dynamic specifications for discrete choice.

According to Feder et al (1985), agricultural technology adoption has long been of interest to social scientists because of its importance in increasing productivity and efficiency. In developing countries adoption started after the Green Revolution in Asian countries. Since then several studies have been undertaken in Asia, Africa and Latin America to assess the rate, intensity and determinants of adoption. A number of factors affect technology adoption. These include farm size, risk and uncertainty, human capital, labour availability, credit constraint, land tenure system, supply constraint and aggregate adoption over time. Several studies have been undertaken to explain how these factors affect technology adoption.

Basley and Case (1993) and Rosenzweig (1995) revealed that learning from our own experience and learning from neighbours' experience are both important determinants of adoption. These findings are in contrast to earlier investigation by McGuirk and Mudlak (1991) that showed that adoption was constrained by insufficient fertilizer and irrigation not by insufficient information. Another study by Cameron (1999) using panel data confirmed that learning is an important variable in the adoption process.

Boahene (1995) explained the behaviour of Ghanaian cocoa farmers with respect to the adoption of hybrid cocoa. The purpose of the study was to integrate sociological and economic processes in explaining the differences in the adoption behaviour of Ghanaian cocoa farmers. The research involved 103 cocoa farmers interviewed in the Eastern Region of Ghana between February 1992 and August 1992 and from August 1993 to October 1993. Fifty (50) farmers were adopters of hybrid cocoa whereas the remaining fifty three (53) were non-adopters. A logistic regression model was used to determine the importance of the various factors which influence the farmer's adoption of hybrid cocoa.

Variables included in the model were extension information, income, bank loan, and family size. Other variables were age of the farmer, education, hired labour, skill, land size, cooperative labour, network resources, and family labour. Results of the study indicated that information oriented factors such as access to extension information; education and network information play a significant positive role in adoption of hybrid cocoa. Also, resource oriented factors namely a bank loan, hired labour and cooperative labour have significant positive impact in determining the adoption of hybrid cocoa and the percentage area of adoption. There was a negative relationship between land and decision to adopt the hybrid cocoa but a positive relationship between land and the percentage area of adoption. Income and network resources were not significant in either influencing the decision to adopt the hybrid cocoa or the amount of adoption. Age had a significant negative effect on the model about adoption or non-adoption of the hybrid cocoa but a positive effect on the percentage area of land adopted. The study did not however adequately address the reason why farmers were not adopting the hybrid cocoa.

Improving upon the study of Boahene (1995), a multidisciplinary model was employed by Boahene et al (1999) to explain the adoption of agricultural innovations in developing economies with reference to hybrid cocoa in Ghana. They examined both theoretically and empirically the role of profit and other economic variables as well as farmers' social and institutional setting in the adoption process. The questions they sought to answer were: (i) is the economic situation of the farmers more important than their skills and the nature of their social networks in the adoption of hybrid cocoa? (ii) Given the availability of support from acquaintances, are there any differences between adoption behaviour of large scale farmers? (iii) what effect does social status have on adoption behaviour? A logistic regression model was used to examine the factors which distinguish adopters of hybrid cocoa from non-adopters. Results of the study showed that the adoption of hybrid cocoa is a process incorporating different mechanisms and factors both economic and sociological.

Factors such as bank loans and hired labour have significant positive impact on adoption. Also, education and amount of information accumulated from extension agents are important in determining whether or not a farmer becomes an adopter. However access to land, income and skills have no significant effect on adoption. The empirical evidence showed that in adoption of hybrid cocoa, the support that small-scale farmers obtain via their social networks is more relevant than the advantage of farm size enjoyed by large scale farmers. For large scale farmers, access to a bank loan strongly increases their chance of adoption compared to small scale farmers. Also, contacts with extension agents, education, and availability of hired labour also have positive effects on adoption. The social status has only an indirect effect on adoption: farmers with higher social status are more likely to obtain a bank loan and a bank loan has positive impact on adoption.

The study recommends that since government does not have enough money to provide technical advice and credit for all farmers in the cocoa industry there is the need to devise a framework in which the resources obtained from networks and those provided by the government can be integrated. Like the previous study by Boahene (1995), the present study by Boahene et al (1999) did not provide reason why the farmer did not accept the technology even though they had access to credit and labour.

Zeitlin (2009) estimated the impact of sociological factors on fertilizer adoption among a panel of Ghanaian cocoa farmers. He estimated the effect of peer decision on farmers' choice to adopt technology in an endogenous social network. He examined how social interaction between producers shapes their decisions about technology use and the decision to adopt fertilizer as an input in particular. He studied the interaction fostered through farmers' mutual affiliation with cocoa sales outlets, the licensed buying companies (LBCs). The hypothesis for the study was that social influence among producers affiliated with a particular LBC has a causal impact on the adoption choices of individuals. Results of the study suggest a large social multiplier in technology adoption, and suggest a possible dimension of negative associative matching consistent with social learning in the presence of heterogeneous expertise.

Thus, the study draws attention to the need to incorporate social network in adoption studies.

In a similar study, Lawal and Oluyole (2008) studied the factors influencing the adoption of research results in agricultural technologies among cocoa farming households in Oyo State in Nigeria. They used the equation (19) to determine the factors responsible for research results and technologies.

$$Y = f(X_1, X_2, X_3, X_4, X_5, \varepsilon) \qquad \ldots (19)$$

where

Y is adoption of Cocoa Research Institute of Nigeria (CRIN) results and technologies.

X_1 is sources of information

X_2 is educational status of farmers

X_3 is age of farmer

X_4 is visit by CRIN scientists

X_5 is social network/association among farmers.

Semi structured questionnaires were administered to gather the necessary data. The information collected included socio-economic characteristics, sources of information on modern agricultural technologies, and factors contributing to adoption of technologies. The data collected were analysed using both descriptive and inferential statistics. Results showed that 73% of farmers interviewed did not adopt the technologies. Adopters were 27% and were mainly casual workers on CRIN plantations who worked or had a link with technical staff than non-adopters. All the adopters were below 60 years and 80% had at least primary education. The significant determinants of adoption of research results were age of farmer and visit by CRIN scientists. Access to credit, participatory approaches to research and regular training/visits on use of technologies were found to be important for adoption of technologies. Even though this study provides a useful guide in the factors to be included in the technology adoption model, it uses ordinary least squares (OLS) methodology instead of the double hurdle model for the current study.

In a study on the Cocoa High Technology Programme (CHTP) Bosompem, Ntifo-Siaw and Adjei-Kwarteng (2008) used a survey of 200 randomly selected beneficiaries of a micro financing facility in four districts in the Eastern region of Ghana. The credit facility was to increase access by cocoa farmers to high yielding inputs and technologies. There was a partnership agreement between the licensed cocoa buying companies (LBCs), the Cocoa Research Institute of Ghana (CRIG) and the Ministry of Food and Agriculture (MOFA). The LBCs received agro chemicals (the credit) from CRIG and forwarded them to their registered credible farmers. MOFA provided the necessary extension and monitoring support for beneficiary farmers on application of the technology. The credit was deducted from the sales of cocoa to the LBCs. Thus the LBCs bore the full credit risk.

Their findings were that, farmers' yields significantly improved by 72% three years after the programme. However about 81% defaulted because beneficiary farmers diverted their produce to non-partner LBCs thereby preventing the LBCs which advanced the credit from making deductions for loan recovery. The study emphasised access to credit and placed lesser importance to the other determinants of technology adoption.

The study recommended that the partnership agreements should be reviewed to reflect the diverse needs and mutual interests of all partners.

especially the LBCs who were direct implementing institutions. Also, the credit facilitation skills of staff of LBCs should be strengthened. Finally, more effective credit mechanisms should be devised to enhance loan recovery and make the revolving fund concept sustainable.

In their study of factors influencing the adoption of recommended practices by cocoa farmers in Ghana Asante-Mensah and Seepersad (1992) used interviews and questionnaire survey. Data and information were collected from 180 farmers, 63 extension agents and 15 non-cocoa farmers. The study aimed at determining current levels of adoption of 12 selected recommended practices on cocoa production and the factors influencing them. The relationship between the dependent variable of overall adoption of the recommended practices and the independent variables of personal and background characteristics, educational and farm related factors, economic and communicational factors were investigated.

The study revealed that eight (8) of the twelve (12) practices including those considered as critically important for short term increases in cocoa production (e.g. weed control, pest control, recommended cocoa varieties, etc) were adopted by less than one third of the respondents. However, two practices (cultural control method of black-pod disease, and mid-crop harvesting) had a high respondent adoption (over 67% adoption). Two other practices (swollen shoot disease and mistletoe control) had a medium respondent adoption (34 – 66% adoption). Factors contributing to non-adoption, low and partial adoption included lack of knowledge of the practices, and lack of conviction of the merits of some of the recommended practices. Complexity of some practices, inadequate and erratic supply of some farm inputs, prohibitive costs of labour, sprayers and insecticides were also major constraints in adoption of the recommended practices. Inadequate support from the extension system was also found to contribute to the low adoption of recommended practices.

Asante-Mensah and Seepersad (1992) continued that though economic factors were very important in influencing adoption, situational and farm related variables were most important group of variables that influenced overall adoption of the recommended practices. Of communicational factors, persons from whom information was sought and frequency of contacts with the extension agents were significant influencers of adoption but the chief cocoa farmer was not important as channel for communication of innovation. With respect to personal variables, gender was the most important. Female farmers tended to be lower adopters of the recommended practices especially those which are more physically strenuous. In connection with the extension agents, the study also revealed that a large work load, inadequate supervision, lack of transportation, inadequate programme planning and poor incentives for work were factors impeding effective extension work and limiting the success of the rehabilitation programme. Significant among the recommendations made were: provision of incentives for both farmers and extension agents, improvement in the supply of farm inputs, improving transportation for extension agents, the creation of a radio programme on cocoa for farmers and the setting up of an extension monitoring, research and evaluation unit within the Cocoa Services Division. The study thus, provided a useful guide to the determinants of adoption of cocoa technologies.

Aneani, Anchirinah, Owusu-Ansah and Asamoah (2012) investigated the causes of low adoption of the cocoa (*Theobroma cacao*) production technologies recommended to cocoa farmers by Cocoa Research Institute of Ghana (CRIG). To investigate this issue, a sample survey of 300 cocoa farmers was randomly selected using a multi-stage sampling technique from all the cocoa growing regions. Data was collected using a structured questionnaire for the individual interviews. The multinomial logistic regression model was used to investigate the factors that affect the behaviour of cocoa farmers relating to CRIG – recommended cocoa production technologies. The empirical model specified is shown in equation 20.

$$A = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + e \quad \ldots (20)$$

where

A is adoption of recommended production technologies.

X_1 Age of cocoa farmer measured in years

X_2 Working experience (number of years in cocoa farming).

X_3 Educational level of the cocoa farmer (literate or illiterate).

X_4 Gender (male or female).

X_5 Household size.

X_6 Migration, (native or settler).

X_7 Number of cocoa farms owned by farmer.

X_8 Cocoa farm size measured in hectares.

X_9 Age of cocoa farm measured in years.

X_{10} Cocoa yield measured in kilogramme per hectare (as a proxy of cocoa income).

X_{11} The extent of extension visits to farmer's farm by extension officers

X_{12} Attending demonstration or field day (yes or no).

X_{13} Access to credit (yes or no)

Results of the study indicated that the adoption rates of CRIG-recommended technologies such as control of capsids with insecticides, control of black pod disease with fungicides, weed control manually or with herbicides, planting hybrid cocoa varieties and fertilizer application were 10.3%, 7.5%, 3.7%, 44.0% and 33.0%, respectively. Adoption models indicated that credit, number of cocoa farms owned by the farmer, gender, age of the cocoa farm, migration, cocoa farm size, and cocoa yield significantly affected the adoption decisions of cocoa farmers concerning the CRIG-recommended technologies analyzed in this study.

Zeitlin (2009) estimated the effect of peer decisions on farmer's choice to adopt technology in an endogenous social network. Data used for the study was from the Ghana Cocoa Farmers Survey conducted for the Centre for the Study of African Economies (CSAE), in consultation with the Ghana Cocoa Board in 2001/2, 2003/4 and 2005/06. The empirical model estimated was concerned with the decision of individuals to adopt a technology. Denoting by $\omega_{igt} \in \{0, 1\}$ a binary indicator decision of individual i belonging to group g in period t to employ fertilizer, the adoption decision was specified as in equation 21.

$$\omega_{igt} = 1\left[K + x_{igt}\beta_x + y_{g(i),t}\beta_y + \theta\varpi_{g(i),t} + u_{igt} > 0\right] \quad \ldots (21)$$

The coefficient of $w_{g(i),t}$ is average adoption decision of group members $j \neq i$ in group g (i) which captures the endogenous effect. x_{igt} is a 1x r vector of individual characteristics such as gender, age of household head, education, farm size. The 1 x s vector $y_{g(i),t}$ captures contextual effect including the characteristics of other group members and relational characteristics. The model was estimated using an instrumental variables approach. Results of the study suggested a large social multiplier in technology adoption and suggest a possible dimension of negative assortative matching consistent with social learning in the presence of heterogeneous expertise. Even though the factors identified as determinants of technology adoption will be incorporated in the current study, the methodologies employed are different.

In his study of the socio-economic factors that explain the adoption of Green Revolution technology in Ghana, Donkoh (2006) used a probit model to estimate the adoption model. Results of the study indicated that the proportion of GR input adoption was greater for the following: households whose heads had formal education, households with higher levels of non-farm income, credit and labour supply as well as those living in urban centres. He therefore recommends that technology adoption should be taken seriously by increasing the levels of complementary inputs like credit, extension services and infrastructure. Households must be encouraged to join farmer groups. Fundamental problems of illiteracy, inequality and lack of effective markets must be addressed through increasing the levels of formal and non-formal education. This study also provides a guide on the factors which should be incorporated into a model for explaining the determinants of technology adoption in Ghana.

A review of the variables outlined in the studies

The foregoing discusses the various studies according to authors. In the section which follows, the determinants have been discussed according to the variables in question to facilitate assessment of how different they are from the current study.

Age of the farmer

There is a contention on the direction of age in the literature. Age was found to positively influence adoption of sorghum in Burkina Faso (Adesina and Baidu-Forson, 1995). Also, Asante-Mensah and Seepersad (1992) on the study they conducted on factors affecting adoption of recommended practices by cocoa farmers in Ghana reported positive relationship between age and adoption. However, Mulugeta and Crawford (1995) in their study of smaller holder wheat technology adoption in South Eastern highlands of Ethiopia reported that age had a negative effect on the adoption of wheat technologies. In studies on adoption of land conservation practice in Niger (Baidu-Forson, 1999), rice in Guinea (Adesina & Baidu-Forson, 1995), Hybrid cocoa in Ghana (Boahene, Snijders and Folmer, 1999) age was either not significant or was negatively related to adoption.

Education

Studies that have sought to establish the effect of education on adoption in most cases relate it to years of formal schooling. Generally, it is believed education creates a favourable mental attitude for the acceptance of new practices especially of information-intensive and management intensive practices. Studies such as Daku (2002) and Doss and Morris (2001) showed a positive relationship between education and adoption. However, Harper, Rister, Mjeide, Dreas and Way (1990) found a negative relationship between higher education and IPM insect sweep nets in Texas.

Farm size

The theoretical literature suggests that large fixed costs reduce the rate of adoption by smaller farms. Some studies have found positive relationship between farm size and adoption (Feder et al, 1985, Fernandez-Cornejo, 1996); others found a negative relationship (Yaron, Dinar & Voet, 1992, Harper et al, 1990).

Labour availability

Several studies have reported positive effect of household labour availability on adoption of improved agricultural technology. For instance Million and Belay (2004) in their study of factors influencing adoption of soil conservation measures in southern Ethiopia found a positive relationship between availability of household's labour and adoption of soil conservation measures.

Membership of association

Membership of an association is expected to increase the information availability to the farmer and so lead to adoption of improved technology.

Opoku et al (2009) noted that farmers who belonged to the Cocoa Abrabopa Association (CAA) adopted improved technology.

Credit access

Access to credit is expected to increase the probability of adoption. Availability of credit may influence the adoption of technology by relaxing the binding capital constraints that farmers face during initial investments or helps to finance the variable costs associated with production of improved varieties. However study results indicate that the effect of credit on technology adoption may be positive or negative. For instance, in a study of Indian agriculture, Bhalla (1979) reported that small and large firms gave different reasons for not using fertilizer in 1970-71. Lack of credit was a major constraint for small farms whereas large farms had access to credit and increased their income. However, Scobie and Franklin (1977) concluded that access to credit may not encourage adoption if it entails restriction on input use.

The review indicates that data for the study have been mostly cross sectional data. The data cover a particular period or in some cases, were panel data. Method of analysis included logistic regression, ordinary least squares and probit models. Variables included in the models were farm size, risk and uncertainty, human capital, labour availability, tenure system, supply constraints, extension information, access to credit, education, hired labour, land size, cooperative labour, family labour, network resources, among others. The impacts of these variables on adoption have been mixed. Some had positive impacts while others had negative impact and yet still others had no effect.

The difference between the current study and those reviewed is in the area of methodology. Specifically, the present study uses a double hurdle model which simultaneously looks at the adoption and intensity of adoption through one estimation procedure. The present study is similar to the studies reviewed in terms of variables included which are demographic, socio-economic and other factors.

The closest study related to the present one is that of Aneani, Anchirinah, Owusu-Ansah and Asamoah (2012) which looked at adoption of cocoa production technologies by cocoa farmers in Ghana. The study however did not consider the impact of adoption on output. Again, even though it used multinomial logistic regression analysis, it omitted membership of association as one of the explanatory variables. The estimation procedure was a straight forward logit whereas the present study uses a double hurdle model with the first stage being the logit model. Even though the determinants were estimated, their study failed to make appropriate recommendations to improve upon the adoption rates, a gap the present study will fill.

Determinants of intensity of adoption

A review of the literature indicated that determinants of intensity of adoption has been explained using the Tobit model, Heckman model and Double Hurdle models. This review therefore follows the same approach.

Tobit model

The Tobit model was proposed by Tobin (1958) to describe the relationship between a non-negative dependent variable Y_i and an independent variable X_i. The model supposes that there is a latent (unobserved) variable, Y_i^*. This variable is linearly dependent on X_i via a parameter (vector) β which determines the relationship between the independent variable (or vector) X_i and the latent variable, Y_i^*. In addition there is a normally distributed error term μ_i to capture random influences on this relationship. The observable variable Y_i is defined to be equal to the latent variable whenever the latent variable is above zero or otherwise. The Tobit model is explained as in equations 22 and 23.

$$\begin{Bmatrix} Y_i = Y^* if Y_i^* > 0 \\ Y_i = 0 \text{ if } Y_i^* \leq 0 \end{Bmatrix} \qquad (22)$$

Where Y_i^* is a latent variable:

$$Y_i* = \beta X_i + \mu_i \; ; \mu_i \sqcup N(0, \sigma^2) \qquad (23)$$

The Tobit model is a special case of a censored regression model, because the latent variable Y_i^* cannot always be observed while the independent variable X_i is observable. The coefficient β should not be interpreted as the effect of X_i on Y_i. Instead it should be interpreted as the combination of the change in Y_i of those above the limit, weighted by the probability of being above the limit. Also it can be interpreted as the change in the probability of being above the limit, weighted by the expected value of Y_i if above the limit.

According to Ghosh (1991), the Tobit model is superior to the probit model in explaining the intensity of technology adoption. He explained that if a probit model is used to analyse data on say fertilizer adoption, a farmer who adopts the recommended level of fertilizer is treated the same as a farmer who applies one tenth of the recommendation. However, the Tobit model can measure the intensity of adoption when information such as the percentage of area planted to improved varieties, amount of fertilizer/herbicide applied are available. Another method which can be used to measure intensity of adoption is the hurdle model or the double hurdle model.

Adesina and Baidu-Forson (1995) studied farmers' perception and adoption of new technology using data from Burkina Faso and Guinea. Their hypothesis was that farmers' perception of technology characteristics significantly affects their adoption decisions. The analysis was conducted with Tobit models of modern sorghum and rice varietal technologies in Burkina Faso and Guinea respectively. The Tobit model estimated was as contained in equation 24.

$$\left.\begin{aligned} & V_i^* = \beta^T X_i + \varepsilon_i \\ & V_i = 0 \text{ if } V_i^* \leq 0 \\ & V_i = V_i^* \text{ if } V_i^* > 0 \end{aligned}\right\} \quad \ldots (24)$$

Where V_i, a limited dependent variable is the perceived benefit of adoption of the modern variety; V_i^* is an underlying latent variable that indexes adoption; X is the vector of socio-economic and demographic characteristics of the farm household, and the technology perceptions of the farmer; β^T is a vector of parameters to be estimated and ε_i the error term. Results of the study showed that farmers' perception of the four varietal technology characteristics were positively related to the probability of adoption and intensity of cultivation of the improved sorghum varieties. Two farmer characteristics were significant in explaining adoption decisions: the age of the farmer and farmers' participation in on-farm tests.

Using an improved methodology, Abera (2008) analyzed the influences of farmers' learning and risk on the likelihood and intensity of adoption of improved *tef (a cereal grain)* and wheat technologies in Northern and Western Shewa zones of Ethiopia. The study employed Xtprobit and Xttobit and random effect models and panel data of the same farmers from 1997 to 2001. The Xtprobit model formulated was specified as in equation 25.

$$Y_{ijt} = \partial_0 + \partial_1 X_{i1t} + \partial_2 X_{i2t} + \partial_3 X_{i3t} \ldots + \partial_9 X_{i9t} + \partial_{10} R_{ijt-1} + \partial_{11} K_{ijt-1} + \mu_{ijt} \qquad \ldots (25)$$

Where Y_{ijt} is farmers' decision to adopt improved *tef* or wheat technologies at time *t* (equals 1 if the farmer adopted improved *tef* or wheat technologies at least once during 1997 – 2001 and 0 otherwise). *j* refers to the three technologies namely improved seed, fertilizer and herbicide. X_1 farm size; X_2 age; X_3 family labour; X_4 education; X_5 livestock owned; X_6 frequency of development agent (DA) visit; X_7 distance from Addis Ababa; X_8 road condition; X_9 credit; K_{ijt} Knowledge gain and R_{ijt-1} Risk. The vector of model parameters which was estimated as ∂ (∂_0 to ∂_{11}) and μ_{ijt} is the error term. The model to measure the intensity of adoption was specified as in equation 26.

$$A_{ijt} = \beta_0 + \beta_1 X_{i1t} + \beta_2 X_{i2t} + \ldots + \beta_9 X_{i9t} + \beta_{10} K_{ijt} + \beta_{11} R_{ijt-1} + \mu_{ijt} \qquad \ldots (26)$$

Where A_{ijt} measures intensity of adoption of technology *j* [proportion of land area planted to improved *tef* or wheat variety, amount of fertilizer (kg) and herbicide inputs used per hectare by farmer (litres)]. *t* is time and β is the vector of model parameters to be estimated and μ_{ijt} is the error term.

Results of the study indicated that as farmers gained more experience from growing the new varieties in previous years, they continued adoption and increased areas under these varieties. Furthermore, the study revealed that adopters of wheat and *tef* technologies increased their production by 20% and 39% respectively, than non-adopters. The results indicated that awareness, availability and profitability of the new improved *tef* and wheat varieties enhanced farmers' learning and farmers' experience and had positive influence on the likelihood and intensity of improved seed adoption. Improved *tef* and wheat varieties were found more risky than the local varieties. The study further revealed that younger age of farmer, farmers' learning from previous experience, availability of family labour and credit are key determinants of the likelihood and intensity of adoption of improved seed. This study provided inputs for the variables to be included in the present study. There is however a difference in the methodology used.

According to Green (2005) whether a Tobit or double hurdle model is more appropriate for measurement of intensity can be determined by separately running the tobit and the double hurdle models and then conducting likelihood ratio test that compares the tobit with the sum of the log likelihood functions of the probit and truncated regression models .

The Heckman model

The Heckman two-step method also known as the heckit procedure, Heckman lambda or Heckman correction model is due to Heckman (1976). The procedure enables a researcher to correct selection bias based on non-randomly selected samples. The Heckman correction takes place in two stages.

In the first stage the researcher formulates a decision model based on economic theory. This may be a probit to estimate participation decision. Than the inverse Mill ratio which is the ratio of the probability density function to the cumulative distribution function is computed. In the second stage, the inverse Mills ratio is used as an additional explanatory variable. Thus in the second stage the researcher corrects self-selection by incorporating a transformation of predicted individual probabilities as an additional explanatory variable.

The difference between the Heckman model and the Cragg double hurdle model revolve around the assumptions about the farmer's decision at the two stages of the model and whether the decisions can be made simultaneously or not. In the Heckman two step method decision to adopt and intensity of adoption are made sequentially whereas in the Cragg double hurdle model the decision to adopt and intensity of adoption are taken simultaneously. The Cragg double hurdle model is the most flexible of the two stage models as it allows for censoring at either stage of the model. The advantage of the Cragg model is that it allows variables to have differing effects on the adoption decision and intensity of adoption.

Ben-Houassa (2011) employed Heckman's sample selection analysis to investigate the factors which influence the adoption and intensity of use of fertilizer on smallholder farms growing cocoa in Western Cote d'Ivoire. Data was obtained from a survey of 362 households in April-May 2009 in 15 villages in Western Cote d'Ivoire. First, the probability of adopting the input was estimated by means of a probit maximum likelihood function on both fertilizer users and nonusers. The choice of fertilizer adoption by the *ith* household was modelled by the selection model as in equation 27.

$$z_i^* = \alpha X_i + \mu_i \qquad \ldots (27)$$

Where z* is an unobserved latent variable determining household's decision to use fertilizer, X is a vector of farm households' asset endowments, household characteristics and location variable hypothesized to affect the adoption decision, and μ is a random disturbance term distributed with mean 0 and variance 1. The observed binary variable was as specified in equation 28.

$$\left.\begin{array}{l} Z=1 \text{ if } z^* > 0, \text{ (for users of fertilizer)} \\ Z=0 \text{ if } z^* \leq 0, \text{ (for nonusers of fertilizer)} \end{array}\right\} \qquad \ldots (28)$$

From the Probit equation the inverse Mill's ratio, (λ) which is the ratio of the ordinate of a standard normal to the tail area of the distribution, can be computed. The Mill's ratio reflects the probability that an observation belongs to the selected sample and is obtained as equation 29.

$$\hat{\lambda}_i = \frac{\phi(X_i\hat{\alpha})}{\Phi(X_i\hat{\alpha})} \qquad \ldots (29)$$

where ϕ is the density function of a standard normal variable, and Φ is cumulative distribution function of a standard normal distribution and λ is the Mill's ratio term.

In the second step, λ is included as an additional variable in the ordinary least squares estimation of the intensity equation for fertilizer-using households. This technique eliminates the potential sample selection bias. If λ is not statistically significant, then the sample selection bias is not a problem. The regression equation for the demand for fertilizer is given by equation 30.

$$y_i = \beta_0 + \beta_1 W_1 + \beta_2 \hat{\lambda}_1 + \xi_1 \qquad \ldots (30)$$

where y is defined as the quantity of fertilizer (kilogram/hectare) used on the plot. W is a vector of farm households' asset endowments, household characteristics and location variable affecting intensity of fertilizer used. ξ is the new residual with the property that $E(\xi)=0$. Results of the study show that factors that tend to significantly affect fertilizer adoption decision are education, membership of association, liquidity, farm size, hired labour, soil fertility, risk aversion and risk perceptions. It was also found that variables like education, access to credit, membership of association, farm size, soil fertility and risk aversion are the most important determinants of the level of demand for fertilizer in cocoa farming. Most of these variables are incorporated in the current study.

Double hurdle model

The decision to adopt or not to adopt a technology is a binary one and the event may lead to generation of several zeros for non-adopters. Having taken a decision to adopt a technology, a farmer may intensify its usage. The adoption and intensity of use decisions can be made jointly or separately. The decision to adopt may precede the decision on the intensity of use and the factors affecting each decision may be different. According to Green (1993) in the case where decision to adopt a technology and how much of it to adopt are not jointly made, it is more suitable to apply a hurdle model.

Cameron and Trivedi (2010) explained a hurdle model as a modified count model in which there are two processes, one generating the zeros and one generating the positive values. The two models are not constrained to be the same. The concept underlying the hurdle model is that a binomial probability model governs the binary outcome of whether a count variable has a zero or a positive value. If the value is positive, the "hurdle is crossed," and the conditional distribution of the positive values is governed by a zero-truncated count model. A hurdle model has the interpretation that it reflects a two-stage decision-making process, each part being a model of one decision. The two parts of the model are functionally independent. Therefore the maximum likelihood (ML) estimation of the hurdle model can be achieved by separately maximizing the two terms in the likelihood, one corresponding to the zeros and the other the positives. The first part uses the full sample, but the second part uses only the positive count observations.

The double hurdle model is designed to analyse instances of an event which may or may not take place and if it takes place, takes on continuous positive values. The double hurdle model was originated by Cragg (1971). In the double hurdle model the adoption decision may be estimated with a probit or logit regression using all observations followed by a truncated regression on the non-zero observations. The non-zero observations may be estimated with a Poisson regression. Teklewold, Dadi and Dana (2006), define the double hurdle model as a parametric generalization of the Tobit model, in which two separate stochastic processes determine the decision to adopt and the level of adoption.

Gebremedhin and Swinton (2003), following Cragg (1971), modelled the decision on adoption using a probit regression as shown in equation 31.

$$f(y=1|X_1,X_2)=C(X_1'\beta) \qquad \ldots (31)$$

In equation 1, f is the functional sign, y represents adoption decision, C(.) is the normal cumulative distribution function. X_1 and X_2 are vectors of independent variables which influence adoption, not necessarily distinct and β is a vector of parameters. The decision on the intensity of use is modelled as a regression truncated at zero as indicated in equation 32.

$$f(y|X_1,X_2) = (2\pi)^{-1/2}\sigma^{-1}\exp\left\{\frac{-(y-X_2'\gamma)^2}{2\sigma^2}\right\}\times\frac{C(X_1'\beta)}{C(X_2\gamma/\sigma)} \text{ for } y>0 \quad \ldots (32)$$

A number of studies have been done on the determinants of intensity of adoption in Ghana and other countries. Opare (1980), investigated the extent to which cocoa farmers in Ghana had adopted recommended cocoa practices. He used questionnaire to gather information from 1191 farmers. The extent of a cocoa farmer's adoption practices was defined operationally in terms of the farmer's score using arbitrary defined indices. A numerical value of zero was assigned to non-adoption and one to the adoption of each practice. Thus, a respondent who had followed all the five recommendations scored five points. Respondents were assessed on the following five practices: mistletoe control, capsid control, swollen shoot management, harvesting and fermentation. The analysis showed that on the average farmers had adopted two practices and had correct knowledge of three out of the five selected recommended practices. The limitation of this study is that it study did not employ any regression analysis; it used only percentages to measure the adoption.

The double hurdle model, which is similar to the Heckman model was employed by Teklewold, Dadi and Dana (2006) to study the factors that determine the rate and intensity of adoption of poultry, assuming the decision processes were separate. The double hurdle model was used because it was possible to segment factors in the adoption process that need to be targeted for improvement.

The double hurdle had an adoption (D) equation as in equation 33.

$$\left.\begin{array}{l} D_i = 1 \text{ if } D_i^* > 0 \text{ and } 0 \text{ if } D_i^* \leq 0 \\ D_i^* = \alpha' Z_i + \mu_i \end{array}\right\} \qquad \ldots (33)$$

Where D* is a latent variable that takes the value 1 if the farmer adopts exotic poultry and zero, otherwise. Z is a vector of household characteristics which include age of household head; sex of household head; level of education of the household head; total family size; total farm size; availability of concentrate; availability of vaccination; total household income; participation in off farm work; availability of credit; access to extension service; availability of market; number of poultry sold and number of years since exotic poultry breed was adopted. α is a vector of parameters and μ_i is error term.

The level (or intensity) of adoption (Y) is specified as in equation 34.

$$\left.\begin{array}{l} Y_i = Y_i^* \text{ if } Y_i^* > 0 \text{ and } D_i^* > 0 \\ Y_i = 0 \text{ otherwise} \\ Y_i^* = \beta' X_i + v_i \end{array}\right\} \qquad \ldots (34)$$

Where Y_i is the observed answer to the proportion of exotic breed, and X is a vector of individual's characteristics and β is a vector of parameters and v_i error term.

The error terms μ_i and v_i are distributed as follows:

$$\begin{Bmatrix} \mu_i \sim N(0,1) \\ v_i \sim N(0,\sigma^2) \end{Bmatrix}$$

The log-likelihood function for the double hurdle model is:

$$LogL = \sum_0 \ln\left[1-\Phi(\alpha Z_i')\left(\frac{\beta X_i'}{\sigma}\right)\right]\sum_+ \ln\left[\Phi\left(\alpha Z_i'\right)\frac{1}{\sigma}\phi\left(\frac{Y_i-\beta X_i'}{\sigma}\right)\right] \quad \ldots 35$$

Where Φ and ϕ are the standard normal cumulative distribution function and density function, respectively. The first portion is the log-likelihood for a probit, while the second portion is the log-likelihood for a truncated regression with truncation at zero.

The model was fitted to a sample of 200 smallholder farmers from East Shewa and Welayeta zones in Ethiopia. The dependent variable in the first stage probit equation was farmers' adoption of exotic breed. Proportion of exotic breed in the household was used as the dependent variable in the second stage truncated regression. Results of the study indicated that 41.5% of the farmers reported adoption of exotic poultry with a mean proportion of 0.54. There were different sets of factors behind the decision to adopt and intensity of adoption. Farmers' decision on adoption of poultry technology was positively affected by sex of the household head, family size, availability of supplementary feed, credit and extension service and extent of expected benefit from poultry and negatively affected by market problem. On the other hand, the farmers' decision on the extent of adoption of exotic poultry breed was positively influenced by the age of the household head, experience in adoption poultry technology, expected benefit from poultry and negatively influenced by market problem. This study provides a useful guide for the estimation of the double hurdle model and the factors to be incorporated in the model.

In their study of household resource endowment and determinants of adoption of drought tolerant maize varieties, Legese, Langyintuo, Mwangi, Jaleta and Revere (2009) used the double hurdle approach. They used data from 369 households in the Adama and Tulu Jido Kombolcha districts in Ethiopia. The households were stratified into poor and well endowed categories based on wealth indices constructed using their productive assets by the principal component method. A double hurdle model similar to that of Teklewold, Dadi and Dana (2006) was then specified and estimated for each wealth group to assess factors influencing adoption and use intensity of improved varieties. The results indicated that factors influencing adoption and use intensity of improved maize varieties among 61% of the poorly endowed households differed from those observed for the well endowed households. The study therefore recommended specific interventions to improve the adoption and use intensity of improved maize varieties among farmers in the two and similar districts of Ethiopia. However, the impact of the technology adoption on output was not examined.

Another study which used the double hurdle model was that of Shiferew, Muricho, Okello, Kebede and Okacho (2010) that dealt with adoption of improved groundnut varieties in Uganda. The study examined the factors affecting the decision to adopt and the intensity of adoption of improved groundnut varieties in Uganda. The multi-hurdle regression analysis was used to identify the specific factors that determine access to information, seed supply and capital constraints and the overall demand for new varieties conditional on overcoming these hurdles. Participation in farmer groups and distance to information centres were critical for accessing variety information. Seed supply constraints were overcome by good links with local seed sellers, extension and membership in seed production groups. The results indicated that productive assets like bicycles and farm size were related to improved access to information, seed and capital which enabled adoption of new varieties. Furthermore, the study indicated that in the absence of public intervention resource poor and marginal farmers lacking market access, household assets, human capital and farm size may lag behind or face stiff barriers that may exclude them from harnessing new technologies.

The double hurdle model was also used by Olwande, Sikei and Mathenge (2009) on a ten year panel household survey data for 1,275 households to examine the determinants of fertilizer adoption and use intensity in Kenya. The first hurdle was a sample selection model estimated with a probit model. The second hurdle involved an outcome equation which used a truncated model to determine the extent of adoption (intensity of use) of the technology. The empirical model for the study was specified as in equation 36.

$$\begin{aligned} Adopt = {} & \beta_1 Age + \beta_2 Gender + \beta_3 Education1 + \beta_4 Education2 \\ & + \beta_5 Education3 + \beta_6 Hsize + \beta_7 Dratio + \beta_8 Credit + \beta_9 Land \\ & + \beta_{10} Crop + \beta_{11} Fertkm + \beta_{12} Extkm + \beta_{13} Roadkm + \beta_{14} AEZ1 \\ & + \beta_{15} AEZ2 + \beta_{16} AEZ3 + \beta_{17} AEZ4 + \beta_{18} AEZ5 + \beta_{19} AEZ6 + \beta_{20} AEZ7 \end{aligned} \quad \ldots (36)$$

Where *age* is age of household head: *Gender* is gender of household; *Education1* is dummy for formal education by household head; *Education2* is dummy for secondary education by household head; *Education3* is dummy for post-secondary education by household head; *Hhsize* is household size; D*ratio* is dependency ratio: *Credit* is whether household received credit during the cropping year; *Land* is size of land owned by household; *Crop* is whether household had grown major cash crop; *Fertkm* refers to distance from household to nearest fertilizer seller; *Extkm* is distance of household to nearest extension service AEZ provider; *Roadkm*; distance from the nearest motorable road; *AEZ1* is dummy for coastal lowlands; *AEZ2* is dummy for eastern lowlands; *AEZ3* is dummy for Western lowlands; *AEZ4* is dummy for Western transitional; *AEZ5* dummy for western highlands; *AEZ6* is dummy for Central highlands and *AEZ7* was dummy for marginal rain shadow.

Results of the study indicated that the proportion of household using fertilizer increased dramatically in the last decade while fertilizer application rates increased marginally. The results further indicated that age, education, credit, presence of cash crop, distance to fertilizer market and agro ecological potential are statistically significant in influencing the probability of adopting fertilizer. The strongest determinant of fertilizer use intensity were gender, dependency ratio, credit, presence of cash crop, distance to extension service and agro ecological potential. The study provides a useful guide to the present one in terms of estimation of the intensity of adoption of technology.

Gebremedhin and Swinton (2003) also used a double hurdle statistical analysis of 250 farms in the Tigray region of Ethiopia. The dependent variables were stone terraces and soil bunds. The explanatory variables were market access factors; physical factors, capacity factors, land tenure security factors, socio-institutional factors and household demographic factors. A likelihood ratio test rejected the Tobit model in favour of the double hurdle model. Results of the study indicated that factors affecting level of investment were different from those that affect the decision to invest. Whereas capacity factors largely influenced the adoption decision, expected returns carried more influence for the intensity of stone terrace adoption (measured as metres of terrace per hectare). The opportunity costs of labour and forgone land productivity were strong determinants of level of investment, despite making no significant contribution to the decision to invest. This suggests that activities that use labour in the dry season when bunds and terraces are constructed and maintained (such as migration, local off-farm activity and food-for-work programs) may compete with soil conservation.

Another study by Worku (2011) used the double hurdle model to estimate the decision to adopt and on how much to invest in land conservation in the Ethiopian Highlands. Primary data collected through interview of rural households in three rounds in 2000, 2002 and 2004/5 was used for the study. The study used various techniques to analyse the data, including descriptive statistics and econometric analysis. The econometric analysis involved the use of the two-step double hurdle model. The empirical model for estimation was specified as in equation 37.

$$I_{tij} = \beta_0 + (Poverty_{t-1i})\beta_1 + (Tenure_{tij})\beta_2 + (Market_{ti})\beta_3 + (Plot_{ij})\beta_4 + v \quad \ldots (37)$$

Where

I_{ij} represents the level of land conservation investment made by the farm-household i on plot j as measured by the length of land conservation structures per hectare over the last 12 months;

β_0 represents the constant term;

$Poverty_{t-1i}$ includes measures of income and asset levels of farm-household i over the year prior to the last 12 months;

β_1 is a vector of parameters each corresponding to a variable in the vector $Poverty_{t-1i}$;

$Tenure_{tij}$ represents variables measuring degree of tenure security by the farm-household i on plot j over time t period;

β_2 is a vector of parameters each corresponding to a variable in the vector $Tenuret_{ij}$;

$Market_{ti}$ is related to market access variables associated to the farm-household i over the time t period;

β_3 is a vector of parameters each corresponding to a variable in the vector $Market_{ti}$;

$Plot_{ti}$ represents variables measuring physical.characteristics pertinent to plot j of the farm household i over the time t period;

β_4 is a vector of parameters each corresponding to a variable in the vector $Plot_{tj}$;

v is the error term catering for other controlling variables.

The adoption decision hypotheses were tested using probit regression equation whilst the intensity of adoption hypotheses were tested using truncated regression equation. Results of the study indicated that plot-level decision to adopt land conservation investment and plot-level decisions about how much to invest appear to be explained by different processes. The relevant policy and program tools for encouraging land conservation investment depends on whether or not farm-households are already convinced of the need to adopt land conservation investments at the specific plot. Poverty related factors (such as household characteristics and asset wealth endowment) seemed to have mixed effect on adoption as well as intensity decisions. While a farmer's adoption decision is influenced by whether or not the plot is owner operated (a measure of risk for the immediate period), intensity of conservation is measured by expectation on certainty to cultivate the land for the next five years, farmers' belief on land ownership and distance of plot from home. The limitation of this study is that it did not provide details of how the double hurdle model was estimated.

In a related study, Ketema and Bauer (2012) also explored the determinants of adoption and labour intensity of stone-terraces in Eastern Highlands of Ethiopia. The study used a household and plot-level data collected from 211 farm households and applied the double hurdle model for analysis. The probit regression was used to measure the decision to adopt whilst the truncated regression was used to estimate the intensity of adoption. Results of the study indicated that there are some differences in terms of magnitude and direction of determinants significantly affecting decisions to adopt terraces and its intensity in terms of labour use. The decision to adopt terraces and the decision on its intensity in terms of labour use are both positively and significantly affected by plot size, slope, and ownership of the parcel; training, age, and level of education of household head; proportion of land planted and involvement in off / non-farm activities. The two decisions were negatively and significantly affected by fertility status of the plot and the proportion of female members in the farm.

Most of the studies reviewed measured intensity in terms of area under cultivation. In the current study, however, intensity is measured by the degree of utilization of a particular input such as fertilizer or agro-chemical. Also, all the previous studies used cross sectional data. The predominant methodology was the double hurdle model even though one study by Abera (2008) used Xtprobit and Xttobit. Other studies also used tobit model and Heckman sample selection analysis. The present study will also employ the double hurdle model, consistent with the studies reviewed. Variables included in the models reviewed are inputs such as improved seed, fertilizer, insecticides, herbicides, demographic factors such as age, gender, family size, education and socio-economic variables such as access to credit, availability of labour, extension service, expected benefits, membership of an association. Even though one study by Zeitlin (2009) was on cocoa, it did not employ the double hurdle model. The closest in terms of methodology is Ben-Houassa's study on cocoa in Cote d'Ivoire which employed Heckman's sample selection analysis.

Impact of technology on adoption on output

The review begins with econometric approach to the measurement of efficiency. This is followed by a discussion of various studies on the impact of technology adoption on output. The section ends with a discussion on the differences between the previous studies and what the current studies intends to achieve.

Sena (2003) described four econometric approaches to the measurement of efficiency. These are the Cross-sectional model, Panel Data Models, Semiparametric methods and Data Envelopment Analysis. Assuming a cross section of n producers using a vector of inputs x to produce y; using a Cobb-Douglas functional form, the production technology can be represented by equation 38.

$$\ln y_i = \alpha + \beta \ln x_i + \mu_i + v_i \qquad i= 1, \ldots, n \qquad \ldots (38)$$

where β is the vector of technology parameters to be estimated with u_i and v_i as error terms. The error term is assumed to have two different components: a stochastic one, v_i, picking up all random factors which can affect (positively and negatively) production, having the usual Gaussian properties and systematic component, $u_i \leq 0$, measuring (in) efficiency and so all factors which systematically affect production adversely. For estimation purpose it is assumed that it is distributed independently of v_i and that it is truncated. Parametric methods use econometrics to estimate the best practice frontier (i.e. the production technology of the best performer in the industry under analysis) and at the same time, after deriving a measure of the estimated residual measure of the technical efficiency (TE) as in equation 39.

$$TE = \exp(-\mu_i)/v_i \qquad \ldots (39)$$

Two methodologies developed to measure technical efficiency using panel data sets are the traditional panel data estimators (fixed and random effects) and maximum likelihood (ML) estimators. Sena (2003) believes the traditional panel data estimator was initially proposed by Schmidt and Sickles (1984) who specified the production frontier model as contained in equation 40.

$$\ln y_{it} = \alpha_0 + \beta \ln x_{it} + \mu_{it} + v_{it} \qquad t = 1, \ldots, T \quad i = 1, \ldots, N \qquad \ldots (40)$$

Outputs and inputs can now vary across time and producers. Statistical noise (v_{it}) varies over producers and time, but technical inefficiency (u_{it}) varies only over producers. The firm-specific inefficiency term can be merged with the constant to obtain a conventional panel data model as shown in equation 41.

$$\ln y_{it} = \alpha_1 + \beta \ln x_{it} + v_{it} \qquad \ldots (41)$$

Equation 41 can be estimated either by the fixed effects (FE) (by using dummy variables to account for individual effects or, alternatively, by applying ordinary least squares (OLS) on the deviations of the time means) or by the random effects (RE) estimator (a GLS estimator) where the inefficiency component is allowed to be random. Efficiency scores are then computed by comparing the estimated α_i of each producer to its maximum estimated value.

According to Sena (2003), maximum likelihood (ML) estimation requires both a distributional assumption on the error components and a functional form for the production technology. Both requirements can be a source of misspecification and attempts have been made to relax any of the two assumptions by using semi-parametric econometrics. However in spite of the fact that there exist a significant number of semiparametric estimators, these cannot be considered to be a unified corpus of alternative estimators to the parametric ones; on the contrary they tackle specific problems arising from the implementation of the parametric estimators.

The linear programming approach to the construction of the production frontier is known as Data Envelopment Analysis (DEA). It is non-parametric as it does not require an explicit functional form and constructs the frontier from the observed input-output ratios by linear programming techniques.

A number of studies have been done on the impact of technology adoption on output. In their study of the impact of modern technology adoption on output growth and the sustainability of major cereal production in Bangladesh, Islam (2002) used a time series database on major cereal production. The study area consisted of 17 greater districts in Bangladesh, characterized by different agro-ecology. The growth rate of major cereals production was measured using a compound growth rate model, while the sustainability of modern food grain production technology was measured by estimating Total Factor Productivity (TFP), using the Tornqvist Theil (TT) index. A moment based production function was used to estimate factors affecting the sustainability of modern food grain production technology. The model was estimated by the generalized method of moment procedure. Specification of the stochastic production function used in this study was as Just and Pope (1979) proposed a more general model with an additive heteroscedastic error of the form contained in equation 42.

$$\left.\begin{aligned} Y &= f(x,\beta)+e^{*} \\ Y &= f(x,\beta)+h(x,\Omega)^{1/2}e \\ E(e) &= 0, V(e)=1 \end{aligned}\right\} \quad \ldots (42)$$

where

$f(x, \beta)$ = the deterministic component of the production function.

$h(x, \Omega)$ = the stochastic component of the production function.

Y = output (kg per hectare),

X= the vector of inputs Xj, j = 1,2, …, 7 with

X_1 = irrigated area (ha),

X_2 = fertilizer used (kg per hectare),

X_3 = pesticide used (kg per hectare),

X_4 = humidity,

X_5 = monthly average rainfall (mm.),

X_6 = monthly average temperature (^oC).

X_7 = Regional dummy

e = a random error term; u= N (o,σ^2),

β and Ω are the parameters to be estimated

This model allows inputs to have distinct effects on the mean, $E(Y) = f(x, \beta)$ and the variance, $V(Y) = h(x, \Omega)$ of output. So the effects on mean and variance of output can be independent. For estimation of production distribution function, both $f(x, \beta)$ and $h(x, \Omega)^{1/2}$ were specified as popular log-linear form and the Cobb-Douglas production function.

The results of the study indicated that good progress in the adoption of modern variety (MV) rice was achieved during 1970s and 1980s because of the release of high-yielding varieties (HYVs) and government subsidies on fertilizers, pesticides, and irrigation. In general, positive growth rate in MV rice production was achieved due to the area expansion of MV rice. Yield for all three seasons MV rice declined. Yield reduction could be attributed to the degradation of soil fertility due to intensive cultivation, inappropriate fertilizer application, deficiency of micronutrients in soils, and a general deterioration in varietal traits. The results further indicated that since independence, the area and production of all cereal crops in Bangladesh has increased. However, with the exception of wheat, yields have decreased. The estimates of TFP indices of MV Aus, Aman, Boro and wheat indicated that modern food grain production technology became unsustainable after the mid-1980s. It revealed that MV Aus production technology was sustainable up to 1983, MV Aman technology was sustainable until 1985, and MV Boro was sustainable until 1989. MV wheat production technology was sustainable until 1984, indicated by a declining trend in TFP indices. The study also identified and quantified the impact of technological (fertilizer, pesticides etc.) and environmental factors (rainfall, humidity etc.) on the sustainability of modern rice and wheat production in Bangladesh using production distribution moments. The only limitation of the study is that it did not provide details of the total factor productivity.

In a related study, Nakamura and Ohashi (2007) examined the effect of technology adoption on productivity and industry growth using the plant-level data pertaining to the Japanese steel industry. They estimated the Cobb-Douglas production function, considering the differences in technology between the refining furnaces owned by a plant. Results of the study indicated that a more productive plant was likely to adopt the new technology and that the adoption would be expected to occur immediately following the peak of the productivity level achieved with the old technology. The adoption of the new technology primarily accounted not only for the industry's productivity slowdown but also for the industry's remarkable growth. This study is however not on agricultural technology adoption.

Improving on the earlier studies, El-Osta and Morehart (1999) used data from the 1993 Agricultural Resource Management Study to examine the impact of technology adoption on production performance of a sample of dairy farms. The study used a deterministic parametric frontier as was originally proposed by Green (1980) of the form specified in equation 43.

$$Y_i = [\,\alpha + f(X_{ij};\beta)\,]\exp[(D_{iq}, T_{im};\gamma) + \mu_i] \qquad \mu_i \leq 0 \qquad \ldots (43)$$

Where Y_i is output of milk sold by the ith farm (i = 1, …, n) measured in hundred weights (cwt); X_{ij} (j= 1, …, k) is a vector of aggregate inputs; $f(X_{ij};\beta)$ is a milk production function D_{iq} is a dummy variable of region q; T_{im} is a dummy variable denoting technology m (i.e. T_{im} = 1 if adoption occurs, 0 otherwise); α is a constant; β and γ are vectors of unknown parameters; exp is exponential function, and μ is deviation from the production frontier and as specified, represents technical inefficiency.

Findings showed that the adoption of a capital or a management intense technology would measurably lower the likelihood of a farmer being in the lowest quartile of production performance. The economic cost of milk production by the top-performance group were estimated to be 53% lower than those by the low-performance group, providing evidence of the importance of improved production practices to the viability of many dairy operations. This study uses the production frontier approach and thus, is different from the current study in terms of methodology employed.

A study by Maffioli and Rozo (2009) evaluated the impact of agricultural extension services in the Dominican Republic. In particular, they analyzed the direct impact of the Program for Technological Support in the Agricultural Sector (PATCA) on adopter's productivity and value of production. The analysis relied on a unique dataset gathered by PATCA's executing unit in 2008. The survey included 1,572 farmers operating in crop growing, breeding or milk production. Using a propensity score matching technique, they found that the technologies financed through PATCA effectively improved the productivity of rice producers and breeders. However, they did not find any significant impact on other producers. These heterogeneous impacts could be due to the different level of effectiveness of the promoted technologies in the short run, where land levelling and pasture conservation could be the fastest in showing significant effects. Finally, they did not find any clear evidence that the program had a significant impact on the quality of production that was reflected on prices reported by farmers.

To examine the impact of reduced subsidies on inputs and whether innovation has occurred in the Ghanaian cocoa sector after market reforms in the 1980s, Teal and Vigneri (2004) used OLS and Heckman Selection analysis. They analysed the evolution of cocoa production growth in Ghana in the 1990s: a period of agricultural reforms that was expected to significantly affect the sector due to both macro liberalisation and the internal liberalisation of cocoa marketing. In particular they examined the impact of subsidies on inputs supply and the possible role of technical change in effecting rises in cocoa production. They estimated the production function for cocoa in Ghana drawing on two household surveys covering the period from 1991 to 1998 using equation 44.

$$\ln(cocoa) = \beta_1 + \beta_2 \ln(farmsize) + \beta_3 \ln(input) + \beta_4 \ln(labour) + \beta_5 \frac{L_H}{L_T} + \beta_6 \ln(farmvalue) + \beta_7 Dhhedu + \beta_8 hhhsex + \beta_9 \ln(rain) + \gamma T \quad \ldots (44)$$

Where:

cocoa = kilos of cocoa produced

farm size = total hectares of cocoa farms cultivated by each household

input = amount of non labour input use

labour = Man-days of labour (both household and hired)

LH/LT = % of hired labour in total labour

hhh sex = dummy =1 if household head is male

Dhh edu = dummy = 1 if household head has primary school education

farm value = value of all land holdings owned/operated by the household on which any cocoa is growing

$rain$ = regional amount of rainfall

T = time trend = 1 if year==1997, the measure of TFP

The results showed that the increase in household output had been very modest at 6 per cent. While the effect of liberalisation had been to raise the price of inputs they found that the contribution of such inputs to cocoa production had increased both relative to land and very substantially relative to labour. The ratio of both land and non-labour inputs to labour rose implying a rise in labour productivity of 39 per cent while land productivity was unchanged. They found no evidence that reforms had led to innovation in techniques which raised total factor productivity.

In a similar study, Vigneri (2008) investigated the factors that accounted for increased cocoa output in Ghana between 2002 and 2004. Data for the study was from the Ghana Cocoa Farmers Survey (GCFS) conducted in 2002 and 2004. The study estimated a standard Cobb-Douglas production function with three conventional inputs: land, labour, and non-labour inputs (fertilizer, insecticides, and agricultural equipment), a number of household characteristics which have important effect on the level of cocoa production and rainfall. Equation 45 shows the model estimated.

$$\begin{aligned}\ln(cocoa) &= \beta_1 + \beta_2 \ln(farmsize) + \beta_3 \ln(Input) + \beta_4 \ln(labour) \\ &+ \beta_5 farmerage + \beta_6 farmersex + \beta_7 \ln(rain) + \gamma T\end{aligned} \quad \ldots (45)$$

where:

ln is natural logarithm

$Cocoa$ = kilogram of cocoa produced

$farmsize$ = Total hectares of cocoa farms cultivated by each household

Input = Amount of non labour input use (differentiate in regression between fertilizer and insecticide)

labour = Man-days of labour (both household and hired)

farmer age = Age of farmer in years

farmer sex = Dummy, 1 if household head is male

rain = District level amount of annual rainfall (measured as annualised monthly millimetres of precipitation)

T = Time trend, equals 1 for crop year 2004 (to proxy for total factor productivity).

Equation 45 was used to estimate by OLS the determinants of the volume of cocoa production, first for each year separately, and then pooled across time with a time dummy to proxy for total factor productivity (TFP). In order to remove the potential bias of OLS parameters due to the effect of unobserved characteristics of the variable inputs (for example effort of labour, and land quality), the pooled production function was also estimated using a fixed effect model. Finally, a two stage least squares (2SLS) regression was run to explain the impact of fertilizer to production. Results of the study indicated that three key causes of the output boom were increase in labour input, the dramatic rise in the use of fertilizer and good weather. This study is similar to the present study in terms of factors incorporated in the model and the methodology. The present study however uses only OLS to estimate the impact of intensity of adoption of technology and other farmer characteristics on cocoa output.

Unlike the earlier studies, Richman (2012) investigated the drivers of technical efficiency among cocoa farmers in Ghana using a panel data for the period 2001/02 to 2005/06 cocoa seasons. A panel version of the stochastic frontier model was estimated to obtain coefficients of technical efficiency. The Random-effects Tobit estimator was used to estimate the determinants of technical efficiency (TE). The determinants of TE were decomposed into four categories: demographic (X^{d}_{it}), labour (X^{l}_{it}), non-labour (X^{nl}_{it}) including plot size and events or problems (X^{e}_{it}). With the values of the technical efficiency indexes (TE), right and left censored as in equation 46.

$$\left.\begin{array}{l} TE_{it} = y^* \geq 0\% \text{ left censored} \\ TE_{it} = y^* \leq 100\% \text{ right censored} \end{array}\right\} \qquad \ldots (46)$$

This generates the Tobit panel data model contained in equation 47.

$$TE = \alpha_i + X^{d}_{it}\pi + X^{l}_{it}\beta + X^{nl}_{it}\gamma + X^{e}_{it}\delta + v_{it} \qquad \ldots (47)$$

X^{d}_{it} include farmer's relationship with the head of household, age, gender and educational status of household head, (X^{l}_{it}) includes maintenance days, fraction of household days, and an interactive term between education and maintenance days – a proxy for impact of extension education;, (X^{nl}_{it}) non labour inputs including plot size and (X^{e}_{it}) include black pod infestation, termites and other rodent or insects attacks, etc. π, β, δ and γ are vector of parameters to be estimated and v is a stochastic error term assumed to be normally distributed with $N(0, \sigma^2_v)$

The estimate of technical efficiency suggests that cocoa farmers produce only 44.2% of the efficient output and farmers in the western region were more efficient than those in Ashanti and Brong Ahafo. The analysis further indicated a rising trend of mean efficiency scores over the study period. Average efficiency grew by 1.9% and 3.7% in 2003/04 and 2005/06 cocoa seasons. The Random-effects Tobit estimator suggests that demographic factors such as age, gender, relation to household head and education had positive impact on technical efficiency but household size had a negative impact on technical efficiency.

Non labour inputs including maintenance days, plot size, fertilizer usage and use of spraying machine had positive impacts on technical efficiency. An interactive term between education and maintenance used as a proxy for quality of farm maintenance had a positive and significant impact on technical efficiency suggesting that although maintenance of cocoa farm was important (indicated by the positive and significant coefficient of maintenance days), quality maintenance practices (extension education of farmers on best maintenance methods) will further improve farm efficiency. Fertilizer intensity was found to be an important determinant of technical efficiency.

The study controlling for demographic factors and non labour inputs found TE as a negative function of farm level events. Black pod, apart from other problems, was the most important event reducing technical efficiency. Mistletoe, termites and swollen shoot attacks were also found to have significant influence on farm efficiency. Other farm problems as flooding, weeds and bushfires had significant impact on TE.

Richman's (2012) study therefore concludes that among other factors the quality of farm maintenance, farmer's educational status, fertilizer intensity and the use of farm inputs will improve technical efficiency while farm level events warps efficiency. It is therefore advised that efforts at raising productivity and efficiency must work towards improving farmers' education and maintenance practices, and encourage the use of fertilizers. These findings provide useful input for the present study.

Another study on the relationship between hybrid cocoa and land productivity of cocoa farmers in the Ashanti region of Ghana was conducted by Wiredu, Mensah-Bonsu, Andah and Fosu (2011). Data was obtained from 366 randomly selected cocoa farmers. 43.72 per cent of the farmers were adopters of hybrid cocoa varieties. Some of the farmers used insecticides, fungicides, fertilizer, termicide and weedicides. Others have replanted their old cocoa fields. The study employed both Probit and Tobit regression models to estimate technology adoption. Intensity of adoption was measured by the area allocated to hybrid cocoa varieties.

In order to capture the contribution of hybrid cocoa varieties to the recorded increases in land productivity, two models were generated. In the first model, adoption is introduced as a discrete variable to assess the effect of the decision to adopt on productivity. Again adoption was introduced as a continuous variable to assess the effect of the extent of adoption on productivity. Adoption was shown to be endogenous with insignificant effect on productivity when fitted to an ordinary least square regression model. Instrumental variable procedure was used to correct for endogeneity related to adoption and use of hybrid cocoa varieties.

Results of the study indicated that in addition to the use of hybrid cocoa varieties, land size, labour, age, nativity, participation in cocoa programs and engagement in secondary income activities are shown to be significant determinant of land productivity in the two models. Household size is shown to be significant when adoption is introduced as a choice variable. When adoption is introduced as a proportion of land allocated to cocoa hybrid, the number of extension contacts is shown to be significant. Gender, education, membership of farmer based organizations, credit and social amenities did not significantly affect land productivity in cocoa based production system. Labour positively affected productivity. The Tobit model used is however different from the methodology of the current study.

To study the impact of access to credit on technology adoption and its impact on productivity, Opoku, Dzene, Caria, Teal and Zeitlin (2009) investigated the impact of a private sector initiative [Cocoa Abrabopa Association (CAA)] in Ghana's cocoa industry. The study was part of the Ghana Cocoa Farmers Survey 2008. CAA provided inputs to farmers based on the Hi-Tech package developed by CRIG on credit to groups of farmers. It was expected that the farmers who adopted the Hi-tech would have increased output. Results of the study indicated that there was large evidence of agronomic and economic returns to participation in the programme as output increased by 638.5 Kg relative to the 435 Kg they estimated would have been output levels had farmers not participated in the programme. The study however indicated that there was high dropout rate in spite of the large returns. The reasons for the high dropout rate were not provided.

In a study to analyze the efficiency of resource utilization in cocoa production of cocoa farmers in Ghana Aneani, Anchirinah, Asamoah and Owusu-Ansah (2011) used a random sample of 300 farmers selected from the Eastern, Ashanti, Brong-Ahafo, Central, Volta and Western regions using the multi stage sampling approach. The summary statistics indicated that the mean age of farmers was 51.5 years. The mean working experience was 19.6 years. The average number of adults working on the farm was 3.3 people. Majority of the farmers (52%) had middle school education and 21.5% of them were illiterates. 80% of the respondents were male and 20% females. The mean farm size was 3 hectares and the average cocoa yield was 370 kg/ha.

Regression analysis was employed to estimate the Cobb-Douglas production function from the data for the measurement of technical efficiency of the cocoa farmers. Equation 48 was estimated.

$$\ln Q = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + e \qquad \ldots (48)$$

Where Q= cocoa output in kilogrammes. X_1=Household size (number of household members); X_2 = cocoa farm size in hectares; X_3 = quantity of insecticides in litres; X_4 = quantity of fungicides in satchets; X_5 = quantity of fertilizer in bags; β_i = parameters (elasticities) to be estimated; *e* is the error term.

Results of the regression analysis indicated that the coefficients of household size, cocoa farm size, quantity of insecticides, quantity of fungicides, and quantity of fertilizer were 0.261, 0,514, 0.273, 0.090 and 0.325 respectively. The quantity of fertilizer applied to the cocoa farm had the highest marginal physical product (133.11 kg/bag), and that of quantity of fungicides variable (1.39 kg/satchet) was lowest. Household size, farm size, insecticides, fungicides and fertilizer were found to have statistically significant impact on cocoa output. The sum of elasticities of the factors included in the Cobb-Douglas production function was 1.463, which was more than one, implying that cocoa farmers were operating in increasing returns to scale. Most of the variables in their study will be incorporated in the current study however, the methodology for the current study is slightly different.

In a related study, Kyei, Foli and Ankoh (2011) analysed the factors that affect the technical efficiency of cocoa farmers in the Offinso district in Ghana. Both primary and secondary data were used for the study. Primary data was collected from 100 households in the study area through the administration of questionnaires. Secondary data was obtained from a regionally based cocoa Lincensed Buying Company in Ashanti Region. Data used included technical coefficients (inputs-outputs) of cocoa production such as land, labour, fertilizers, pesticides and capital. Also, socio-economic variables made up of producer's age, level of education, experience in cocoa production, membership of association were used. Farmers' output of cocoa for each crop season was measured in bags. Stata statistical tool was used to estimate the stochastic production frontier function and inefficiency determinants based on socio-economic variables of individual farmers.

The stochastic frontier model estimated was given as equation 49.

$$\begin{aligned} \ln Y_j &= \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 \\ &+ \beta_5 \ln X_5 + \beta_6 \ln X_6 + \varepsilon_j \end{aligned} \qquad \ldots (49)$$

Where

l_n represents a natural logarithm

Y_j is the total output of farm j for the particular crop season

X_1 is the total quantity of bags of fertilizer used during the previous season

X_2 is the total quantity of pesticides (litres) used during the crop year

X_3 is the total land area cultivated by the farmer (acres)

X_4 is the labour employed by the farmer (hired or family stocks)

X_5 the modern equipment available for farmer's usage

X_6 the years of cocoa trees in the farm

ε_j is the error term which measures the inefficiency of the farm j.

Results of the regression indicated that labour force had a negative relationship with output. Also modern equipment and age of trees had a strong negative correlation with output. The results suggest that in the study area cocoa productivity could be enhanced by improving technical efficiency. Factors such as quantity of fertilizer used, pesticides used and farm size had positive relationship with output.

The inefficiency model was given as equation 50.

$$\mu_j = \delta_i + \sum_{i=1}^{10} \delta_i X_{ij} \qquad \ldots (50)$$

Where

μ_j is the error term of farm *j*

δ_i is the constants of variable characteristic *i*

X_{ij} represents the specific characteristics *i* of farm *j*. These characteristics included the age of the farmer; family size of farmer; educational level of farmer; membership of association; access to credit; availability of technical assistance; economic activity of farmers; availability of incentives and age of cocoa plantation. The results of the inefficiency estimates indicated that with exception of age of farms (years of cocoa trees), most of the specific characteristics were not significant. The study thus recommended that factors such as labour, capital and age of farms would lead to increase in output. Also, inefficiency would decrease drastically if variables such as educational level, farming experience and family size of the farmer are increased.

A study similar to the present was by Edwin and Masters (2003) who estimated the yields gains attributable to the breeding of new cocoa varieties in Ghana. They used data from a survey in mid 2002 of 192 farms from the country's key cocoa producing regions. To determine the influence of variety on the productivity of cocoa, they classified the farms by variety used. They used two stage least squares (2SLS) method to estimate equation 51.

$$\ln(yield) = \alpha_0 + \beta_i \hat{h}_i + \mu_i X_i + \varepsilon_i \qquad \ldots (51)$$

where

ln(yield) is the natural logarithm of the yield of cocoa per acre

$\hat{h}$ is the predicted cultivation of hybrid from the first stage regression

X_i denotes additional observed control variable

α_0 and μ_i are unknown parameters, and

ε_i is the error term.

Factors which were included in X were age of the farmer, farm size, quantities of fertilizer, quantities of pesticides, hired labour, family labour, family size, number of dependants, age of the tree, credit and education. To control for endogeneity bias, education and credit access were used as instruments for hybrid cocoa because education and credit gave farmers easier access to the new planting materials.

Results from the study showed that hybrid cocoa is closely correlated with yield, increasing yield by at least 51 per cent, and cocoa yield increases with fertilizer use. Interaction effects between variety adoption and input use are not significant, indicating that the productivity of new varieties is not conditional on input use, but tree age is clearly significant particularly when entered as age squared, indicating that yields decline mainly at high levels of age.

A study not specific to a particular product in the agricultural sector was by Donkoh (2006) who analysed the effects of adoption of Green Revolution technology on output or efficiency and consumption expenditure among agricultural households in Ghana. A stochastic frontier was used to estimate the inefficiency model. Results of the study indicated that efficiency is greater for the following: households living close to extension centres, in the rural areas and in the south of the country. Efficiency is also greater for male-headed households, large households and small farms. Technology adoption was found to have positive effects on households' output. He used a maximum likelihood estimation method to estimate the consumption equation. The consumption model was estimated within the framework of Heckman's two stage method of correcting for sample selection.

Results of the study indicated that technology adoption has positive effect on household consumption. In addition to education and credit, he found household's assets, living in the forest belt and in the south of the country to be positively related to household consumption. The limitation of the study is that it is general and not limited to a particular agricultural product.

How is the present study different from the previous ones? There is no gain saying that technology adoption has impacted on output as revealed by the numerous studies reviewed. The review considered the impact of adoption on various products such as cereal, dairy products, groundnut, and cocoa. Data for the study were mostly cross sectional data. The method of analysis included generalized method, propensity scoring matching, ordinary least squares, tobit models, two stage least squares, maximum likelihood estimation and Heckman two stage model. The studies on cocoa in Ghana (Wiredu, Mensah-Bonsu, Andah & Fosu, 2011; Opoku et al. 2009; Aneani, Anchiranah, Asamoah & Owusu-Ansah, 2011; Kyei, Foli & Ankoh, 2011; Edwin & Masters, 2003; Teal & Vigneri, 2004; Vigneri, 2008; Richman, 2012) did not examine the impact of intensity of adoption on output. Again, the procedure for measurement of the intensity of adoption in the current study is different from the procedure used in the previous studies.

In the current study, apart from determining the intensity of adoption of a particular cultural practice, say fertilizer application, a composite figure for intensity of adoption which is the average of all the percentage of adoption of all the cultural practices has been determined. Basically, the difference between the current study and the previous studies are in the areas of methodology and variables included in the model. Thus, the present study has filled the methodology gap left by the other studies by including intensity of adoption as explanatory variable.

Conclusion

The review revealed that econometric methods used to investigate the determinants of agricultural technology adoption included probit regression, logistic regression, Tobit model, ordinary least squares, truncated regression and double hurdle model. The maximum likelihood approach was central to the measurement of the determinants of adoption. Some determinants of adoption and intensity of adoption of agricultural technology included farm size, risk and uncertainty, human capital, labour availability, and access to credit. Other factors are age of farmer, educational level of the farmer, membership of association and visit by extension officers.

To estimate the impact of adoption on output either the deterministic or stochastic frontier model was employed. The Cobb-Douglas production function was mostly used. Econometric methods used included instrumental variable approach and two stage least squares. The review indicated that adoption of technologies impacted positively on agricultural output. Apart from technology, factors which affected agricultural output included humidity, rainfall, temperature, farm size, labour availability, age of the farmer and gender of the farmer. In chapter four the theoretical framework for the study will be discussed.

CHAPTER FOUR

THEORETICAL FRAMEWORK

Introduction

This chapter deals with the theoretical basis of the study. It begins with the philosophical underpinnings of the study. This is followed by the theoretical framework for the study. In line with the three main themes of the topic, the first part of the framework considers the theory behind adoption, the second deals with intensity of adoption while the third part deals with the impact of adoption on output. The chapter ends with a summary of the theories used for the study.

The philosophical underpinnings of the study

A research philosophy is a belief about the way in which data about a phenomenon should be gathered, analysed and used. According to Orlikowski and Baroudi (1991), research philosophy can be classified as positivist, interpretive and critical. Positivism is described generally as an approach to social research that seeks to apply the natural science model of research to social phenomena. According to Nudzor (2009) positivism is concerned with uncovering truths and facts in terms of specified correlations and associations among variables.

According to Orlikowski and Baroudi (1991), the interpretive philosophy holds the view that the world or reality is not objective, instead, it is presumed to be socially constructed. The central principle of the critical philosophy are that social reality is historically constituted, hence human beings and organisations and societies are not confined to existence in a particular state. The role of the researcher is to expose the hidden contradictions and unfulfilled potential in the societal order and initiate changes in the social relations and practices.

This study uses the scientific method and so associates itself with the positivist. The positivist paradigm of exploring social reality is based on the philosophical ideas of the French philosopher, August Comte. According to him, observations and reason are best means of understanding human behaviour; true knowledge is based on experience of senses and can be obtained by observation and experiment. Positivism relies on quantitative data since they believe that it is more reliable than qualitative data. Positivism follows a well defined structure during studies and discussions. Positivists believe that since there are set laws and rules followed, there will be minimum room for error. This structure also gives little room for variance and drastic variable changes, thus making the study more accurate when it comes to experiments and applications as it tries to follow specific rules using objective mathematical and scientific tools.

Many have criticised the idea that positivist methodology is objective. The approach has been criticised as being tool rooted in functionalism, and concerned with causal analysis at the expense of getting close to the phenomenon being studied. The methodology has been criticised as being inflexible as direction cannot be changed once data collection has started. It is weak in understanding social processes and often does not discover the meaning people attach to social phenomenon. Despite these criticisms, the positivist philosophy is superior to other philosophies in the handling of the topic under consideration.

The study also uses utility maximization and so associates itself with the marginalists who are classical or neoclassical economists. The philosophy behind the study is that farmers are rational economic beings and as such will like to maximize their returns by adopting technologies which will enable them achieve their objectives. The farmers' objectives may be utility or profit maximisation and the constraints may be income, land size, labour, time, among others.

The study considers the determinants of adoption and the impact of adoption on output. The framework is therefore presented along these lines. The first theory deals with determinants of adoption. This is followed by the theoretical basis for intensity of adoption and the last theory deals with the impact of adoption on output.

Determinants of adoption

The utility maximisation theory is used to explain the determinants of adoption. In adopting new agricultural technologies, the decision maker (farmer) is also assumed to maximise expected utility (expected profit) from using a new technology subject to some constraints (Feder et al, 1985).

The decision of whether or not to use a new technology could be considered under the general household model framework of utility or profit maximization. Following de Janvry, Fafchamps and Sadoulet (1991) and Shiferaw et al (2010), the household is assumed to maximise utility function subject to income, production technology and time constraints as indicated below:

$MaxU = U(C_a, C_m, C_l, k, Z_h, \psi)$ Utility function (52)

Subject to the constraints

$p_m C_m \leq p_q(Q_a - C_a) - p_x X(A) + R$ (Income constraint) (53)

$Q_a = Q[x(A), N_f(I), k, Z_h, Z_q, A, \theta)$ (Technology constraint) (54)

$p_x X_2 \leq E + R$ (Credit constrained inputs $x_2 \in x$ (55)

$N_f(A) + C_l \leq T$ (Time constraint) (56)

where C_a is demand for produced agricultural good including cocoa; C_m is demand for manufactured goods, C_l is leisure (home time); Q_a production of agricultural good including cocoa (so that Q_a-C_a is its marketed surplus); k is household endowments of physical capital; Z_h household characteristics; φ other exogenous factors that may affect households preferences such as weather and illness, N_f is family labour used on-farm; R is exogenous income (e.g. transfers and remittances); p_m and p_q are the prices of the manufactured and agricultural goods, respectively; A is area grown under new technology; p_x and X are the price and quantity of farm inputs other than labour; $x_2 \in x$ is the set of credit constrained purchased inputs (while x_l is not constrained); E is credit accessible from different sources; z_q is farm and village level fixed-factors that determine local comparative advantages (e.g. access to markets, infrastructure, farming systems); T is total endowment of family labour time, and θ a random factor that shifts the production function.

The area grown under new technology (A) may change household resource allocation (e.g. fertilizer, labour, land) and thus costs of production. This implies that use of farm inputs will be a function of extent of adoption of the technology (A).

The Lagrangian associated with the constrained maximization can be given as:

$$\begin{aligned} L &= U(C_a, C_m, C_l, k, Z_h, \psi) + \lambda[p_q Q(x_1(A), x_2(A), N_f(A); k, z_q, A, \varepsilon] \\ &- p_x x_1(A) - p_x x_2(A) + R - p_m c_m - p_a c_a] + \rho[E - p_x x_2(A) + R] \\ &+ \gamma[T - L_f(A) - C_l] \end{aligned} \qquad (57)$$

Assuming interior solutions the first order conditions are derived as follows:

$$\frac{\partial L}{\partial A} = \lambda\left[p_q\left(\frac{\partial Q}{\partial x}\frac{dx}{dA} + \frac{\partial Q}{\partial l}\frac{dN}{dA} + \frac{\partial Q}{dA} - p_x\frac{\partial x}{\partial A}\right)\right] - \rho\left(p_x\frac{\partial x_2}{\partial A}\right) - \gamma\left(\frac{\partial N}{\partial A}\right) = 0 \qquad (58)$$

$$\frac{\partial L}{\partial x_1} = \lambda\left(p_q\frac{\partial Q}{\partial x_1} - p_x\right) = 0 \qquad (59)$$

$$\frac{\partial L}{\partial x_2} = \lambda\left(p_q\frac{\partial Q}{\partial x_2} - p_x\right) - \rho(p_x) = 0 \qquad (60)$$

$$\frac{\partial L}{\partial N} = \left(\frac{\partial N}{\partial Q}\right) = \frac{\gamma}{\lambda} = \dot{p_l} \quad \text{(shadow value of family labour)} \qquad (61)$$

$$\frac{\partial L}{\partial C_l} = \mu_l - \lambda\dot{p_l} = 0 \qquad (62)$$

$$\frac{\partial L}{\partial C_i} = \mu_i - \lambda p_i = 0 \quad i \in \text{a, m} \qquad (63)$$

From the above equations, solving for A yields the general function:

$$A = f(p_q, Q, N, x, \rho, \gamma, p_x, Z, T) \qquad (64)$$

Thus technology adoption (A), depends on price of the output (p_q), the quantity produced of the commodity (Q), labour (N), quantity of farm input

(X), interest rate (ρ), wage rate (γ), price of farm input (p_x), household characteristics and total time available (T).

Determinants of intensity of adoption

The intensity of adoption deals with the degree to which a farmer adopts a particular technology. Thus, the farmer must first decide to use a particular technology before he deepens the usage of it. Utility maximisation is therefore also used to explain the intensity of adoption. Following Swinton and Quiroz (2003) the household's intensity of adoption of a technology is modelled as follows:

$$\underset{x}{Max}\, U = U(c, y^c) \qquad \text{Utility function} \qquad \ldots 65$$

Subject to

$$y = y(L_a, x|k, z) \qquad \text{Technology constraint} \ldots 66$$

$$p_c C \leq p_y(y - y^c) - p_x x - p_{ah} L_{ah} + p_{ln} Ln \qquad \text{Budget Constraint} \qquad \ldots 67$$

$$L = L_{af} + L_n \qquad \text{Labour Constraint} \qquad \ldots 68$$

The model states that the farm household chooses the agricultural practices x that will maximize the household's utility from consuming marketed consumption-good c and home produced good y in quantity y^c, subject to the technology of producing good y on the farm, the household budget, and the availability of labour. In terms of technology, the maximization is constrained by the technology for producing good y on the farm, which depends on agricultural labour (L_a) and agricultural practices (x), and is conditioned by farm-level capital (k, in various forms) and other natural and external economic characteristic (z). The budget constraint states that no more of C can be purchased at price pc than the household can afford with net income from sales of y after subtracting home consumption (y^c); the cost of production practices ($p_x x$) and the cost of hired labour ($p_{ah} L_{ah}$), plus income from non-farm employment ($p_{ln} L_n$). Finally, the labour available for own-farm production work (L_a) must either come from the family (L_{af}) or from hired labour (L_{ah}), and family labour may be devoted either to own-farm agricultural work (L_{af}) or to non-farm work (L_n).

The solution of the constrained optimization problem yields a reduced form demand equation:

$$x_{ji} = x_j(p, x_{(j)}, l_a, l_n k, z) \qquad \ldots 69$$

Equation 69 seeks to answer what matters in the choice of farming practices. It shows that the specific farming practice x(j) depends on the price of the output (p), input price x, labour La and Ln, the level of agricultural practices x(j) other than xj; farm capital or asset (k); and conditioning factors (z) related to economic infrastructure, natural characteristics, and the household management knowledge and information.

The impact of technology adoption on output

The theory of production, which deals with the supply of a product, forms the theoretical basis for examining the impact of technology on output. The production function approach is employed widely for examining the impact of physical inputs on production. According to Nicholson (2005), the principal activity of any firm is to turn inputs into outputs. Because economists are interested in the choices the firm makes in accomplishing this goal, but wish to avoid discussing many of the engineering intricacies involved, they have chosen to construct an abstract model of production. In this model the relationship between inputs and outputs is formalized by a production function.

The production function is a function that summarizes the conversion of inputs of capital, labour and other factors into outputs of goods and services. The firm's production function for a particular good, q, shows the maximum amount of the good that can be produced using alternative combination of inputs. According to Koutsoyiannis (2002), the production function is a purely technical relation which connects factor inputs and outputs. It describes the laws of proportions, which is the transformation of factor inputs into products (outputs) at any particular time period. The production function represents the technology of a firm of an industry, or the economy as a whole. The production function includes all the technical efficient methods of production.

A method of production (process, activity) is a combination of factor inputs required for the production of one unit of output. The (basic) theory of production concentrates on efficient method of production. A method of production, A, is technically efficient relative to any other method B if A uses less of at least one factor and no more from other factors as compared to B.

The theory of production describes the laws of production. The choice of a particular technique (among the set of technically efficient processes) is an economic one, based on prices, and not a technical one. A technical efficient method is not necessarily economically efficient. The production function describes not only a single isoquant, but the whole array of isoquants each of which shows different level of output. According to Koutsoyiannis (2002), the general mathematical form of production function is:

$$Y = f(L, K, R, S, v, \gamma) \qquad \dots (70)$$

Where Y = output

L = labour input

K = capital input

R = raw material

S = land input

v = returns to scale

γ = efficiency parameter

All variables are flow, that is, they are measured per unit of time.

In general form, the production function is a purely technological relationship between quantities of inputs and quantities of output. Prices of factors of production do not enter into the production function. They are only used for the production decision of the firm or other economic entities. The efficiency parameter γ refers to the entrepreneurial-organizational aspects of production. Two firms with identical factor inputs (and the same returns to scale) may have different levels of output due to differences in their entrepreneurial and organizational efficiency.

The theoretical model for the impact of technology adoption on output is derived using output maximisation approach under theory of production. Assuming a neoclassical cocoa farmer's production function is characterised by its technologically efficient production function:

$$Q = q(N, K, R, T) \qquad \dots (71)$$

Where Q is output, N is quantity of labour employed, K is the quantity of capital rented. R is the quantity of inputs and T is the technology. The production function is assumed to exhibit diminishing marginal returns. This allows for an early range where increasing returns occurs, a middle range where constant returns occurs and finally a range where diminishing returns occurs. That is to say the production function does not really have a concave or strictly concave over the entire range of interest but only in the range where inputs will be chosen.

The farmer's cost is given as:

$$C = aN + rK + \rho R + vT \quad \dots (72)$$

Where C is cost, w is wage rate, r is interest rate, ρ is price of input and v price of technology. The farmer can maximise output subject to cost as follows:

Maximize $Q = q(N, K, R, T)$

Subject to $C = aN + rK + \rho R + vT$

The lagrangian function is given as:

$$L = q(N, K, R, T) + \lambda(C - wN - rK - \rho R - vT) \quad (73)$$

The first order condition will yield the following:

$$\frac{\partial L}{\partial N} = \frac{\partial q(N, K, R, T)}{\partial N} - \lambda w = 0 \quad (74)$$

$$\frac{\partial L}{\partial K} = \frac{\partial q(N, K, R, T)}{\partial K} - \lambda r = 0 \quad (75)$$

$$\frac{\partial L}{\partial R} = \frac{\partial q(N, K, R, T)}{\partial R} - \lambda p = 0 \quad (76)$$

$$\frac{\partial L}{\partial T} = \frac{\partial q(N, K, R, T)}{\partial T} - \lambda v = 0 \quad (77)$$

$$\frac{\partial L}{\partial \lambda} = C - wN - rK - pR - vT = 0 \tag{78}$$

Thus from (72) to (76)

$$\frac{\partial q(N,K,R,T)}{\partial Nw} = \lambda \tag{79}$$

$$\frac{\partial q(N,K,R,T)}{\partial Kr} = \lambda \tag{80}$$

$$\frac{\partial q(N,K,R,T)}{\partial Rp} = \lambda \tag{81}$$

$$\frac{\partial q(N,K,R,T)}{\partial Tv} = \lambda \tag{82}$$

Solving the above and making Q the subject yields the general equation:

$$Q = f(N, K, R, T, w, r, p, v) \tag{83}$$

It can be deduced from equation 83 that output (Q), depends on labour (N), capital (K), farm inputs (R), technology (T), wage rate (w), interest rate, price of inputs (p) and price of technology (v).

This study uses a stochastic production frontier to explain the impact of adoption of cocoa research innovations and other farmer characteristics on output of cocoa. According to Bravo-Ureta and Pinheiro (1993), the stochastic production model incorporates a composed error structure with a two-sided symmetric and a one-sided component. The one sided component reflects inefficiency while the two-sided error captures the random effects outside the control of the production unit including measurement errors and other statistical noise typical of empirical relationships.

Conclusion

This chapter dealt with the theoretical basis of the study. The decision to adopt a technology and the intensity of adoption is explained by utility maximization approach. Farmers are considered rational economic beings who want to maximize their utility or profit subject to economic and sociological constraints. Thus, the theoretical foundation of determinants of adoption and intensity of adoption is utility maximization.

It is expected that when farmers adopt a technology it will significantly affect the level of output. Measurement of the impact of technology adoption on output is through the production function analysis. Thus, the theory of production is the theoretical basis for explaining the impact of technology adoption on output. In the next chapter, five, the methodology used for the study is provided and discussed.

CHAPTER FIVE

METHODOLOGY

Introduction

This chapter gives explanation of how the study was conducted. It begins with the research design and the rationale for its selection as well as the strengths and weaknesses of the design. This is followed by a description of the study area, the population, sample size and sampling procedure. The instrument used for the study as well as the method for data collection is discussed. Following this, is a description of models used and method of data analysis. The chapter ends with a summary of the methodology employed.

Research design

The survey method was used to collect primary data for the study. According to Kumekpor (2002), social survey is an objective, quantitative approach to the study of social processes within well defined area at a given time through one or more institutions by means of a schedule, or a questionnaire and the data thus obtained related statistically. This method was used because of the wide area the study covered. The areas covered under the study have been discussed under a different heading. The primary data collected through interview schedule covered personal, socioeconomic, institutional and other relevant variables.

Study population

The population for the study was all cocoa farmers in Ghana. According to the report of the Ghana Statistical Service (2008), cocoa supports more than 725,480 smallholder households and the number of cocoa farmers in estimated at 350,000. These farmers are found in all the cocoa growing regions. They consisted of male and female, literate and non-literate farmers of diverse background and ages.

Study areas

The study was done in five regions where cocoa is grown. The five regions are Eastern, Central, Brong Ahafo, Ashanti and Western. Volta region was left out because according to COCOBOD (2011) output of cocoa from that region in 2010/11 which stood at 3,286 tons was less than one percent of the total national output of 1,024,553 tons. A map of Ghana showing the main cocoa growing areas is presented on page 40. The study was conducted in ten (10) cocoa growing districts out of the 69 cocoa districts in Ghana. The method of selecting the districts is provided in the section which dealt with sampling procedure. It is worth noting that some of the cocoa districts are different from the administrative districts of the country.

Table 5 shows a profile of the districts for the study. The land size for the districts ranged from 110 square Kilometres for Koforidua in the Eastern Region to 2,354 square Kilometres in Tarkwa district in the Western Region. Rainfall in the selected districts ranged from 1,200 millimetres to 2,000 millimetres whilst the mean temperature ranged from a minimum of 22 ^{0}C to a maximum of 32 ^{0}C. The vegetation was mostly moist semi deciduous forest. Thus, the districts selected are all conducive to cocoa production.

Table 5: Cocoa districts selected for the survey

Region	District	Land Area KM^2	Rainfall Mm	Temperature ^{0}C
Ashanti	Nkawie	894.5	1700-1850	27.0 – 31.0
Ashanti	Konongo	1,160	1700-1850	26.0 – 30.0
Brong Ahafo	Goaso	1,093	1250-1750	25.5 – 30.0
Brong Ahafo	Dormaa	1,368	1250-1750	26.1 – 30.0
Central	Assin Fosu	1,500	1500-2000	26.0 – 30.0
Central	Twifo Praso	1,199	1200-1750	26.0 – 30.0
Eastern	Koforidua	110	1200-1700	22.0 – 32.0
Eastern	Asamankese	1,018	1238-1660	25.2 - 27.9
Western	Tarkwa	2,354	1200-1878	26.0 – 30.0
Western	Sefwi Bekwai	873	1250-1750	26.0 – 30.0

Source: Ministry of Local Government and Rural Development (www.ghanadistricts.com)

Sample size determination and sampling procedure

It was impossible to deal with the whole population and as such a sample had to be taken for the study. The population used for the determination was 350,000 cocoa farmers. These farmers cover the whole cocoa producing areas.

Sample size determination

The unit of analysis was the farmer who, in most cases, was the household head. The minimum sample size was determined using the following formula proposed by Yamane (1967) and quoted in Israel (2009):

$$n = \frac{N}{1 + N(e)^2} \quad \ldots (84)$$

Where

n is the sample size

N is the population size

e is the level of precision, sometimes called the sampling error.

Using total number of farmers of 350,000 as the population size and the level of precision 5%, the minimum sample size can be determined as

$$n = \frac{350,000}{1 + 350,000(0.05)^2} \quad \ldots (85)$$

This is equal to 399.54, approximately 400 farmers.

A total number of 600 farmers were used in the study to facilitate more coverage. It is worth noting that the number exceeded those used in COCOBOD's Cocoa Farmers' Survey which were 492, 515, and 492 for 2002, 2004 and 2006 respectively (Teal, Zeitlin & Maamah, 2006).

Sampling procedure

The multistage stratified sampling technique was used in selecting farmers for the study. The first stage involved selection of districts. According to the Research and Monitoring Department of COCOBOD, there were 69 cocoa districts in Ghana as at December 2011. Please refer to Appendix G for details. This served as the sampling frame. I selected two districts from each region making a total of 10 districts for ease of computation. The names of the districts were written on pieces of paper which were folded and placed in a container and shaken. The papers were picked one at a time without replacement. Through the random sampling two districts were selected from each region. The districts selected were Nkawie and Konongo in the Ashanti Region; Goaso and Dormaa in the Brong Ahafo Region; Assin Fosu and Twifo Praso in the Central Region; Koforidua and Asamankese in the Eastern Region; and Tarkwa and Sefwi Bekwai in the Western Region.

The second stage involved the selection of villages or communities. This was also done through random sampling. Based on the sample size of 600 and the fact that 10 districts had been selected, I selected 60 farmers from each district for ease of computation. Furthermore, in order not to select all the 60 farmers from one village, I selected 6 villages from each district. The villages were also selected by random picking of the names written on pieces of paper and folded into a small box.

The third stage involved the random selection of farmers. A list of names of farmers from Produce Buying Company Limited (PBC) and Federated Commodities Limited (FEDCO) which are the major cocoa buying companies in the areas served as the sampling frame from which a sample of farmers was selected. The names of the farmers were written on pieces of paper and put in a box. The extension officers were then invited to pick from the bag one at a time names of the farmers to be interviewed. The number of farmers selected for the study is shown in Table 6.

Table 6: Number of farmers selected for the study

Region	District	Population	Number of Villages	Number of Cocoa Farmers
Ashanti	Nkawie	129,375	6	60
Ashanti	Konongo	142,434	6	60
Brong Ahafo	Goaso	110,827	6	60
Brong Ahafo	Dormaa	150,229	6	60
Central	Assin Fosu	116,349	6	60
Central	Twifo Praso	107,787	6	60
Eastern	Koforidua	154,531	6	60
Eastern	Asamankese	154,161	6	60
Western	Tarkwa	232,699	6	60
Western	Sefwi Bekwai	92,834	6	60
Total			60	600

Sources: 1. Population figures are from Ministry of Local Government and Rural Development (www.ghanadistricts.com)

2. Number of villages & cocoa farmers from Field work 2011

Survey instrument and procedures for data collection

The instrument for the study was interview schedule. The questions in the interview schedule were developed based on the kind of information that was required for the analysis. It contained both closed and open-ended questions. Some questions were on Likert scale to enable respondents rank certain items or variables. The interview schedule was divided into eight sections as follows: Section *i* dealt with farmer characteristics; section *ii* considered farm characteristics; section *iii* had questions on social participation; section *iv* sought respondents' knowledge about cocoa research innovations; section *v* treated questions related to technology adoption; section *vi* treated questions on measurement of intensity of technology adoption; section *vii* dealt with output of cocoa; and section *viii* dealt with credit access. Please refer to Appendix H for a sample of the interview schedule.

Pilot Study

Pilot study is the administration of the data collection instrument, for example questionnaire to a small set of respondents from the population for full scale survey. If problems occur in the pilot study it is likely that similar problems will arise in full scale administration. The purpose of pilot study is to identify problems with data collection instrument and find possible solutions. In other words, pilot study is to get the thinking behind the answers so that the researcher can accurately assess whether the questions are understood by respondents and whether the questions ask what the researcher thinks they are asking. Pilot study also helps to assess whether the respondents are able and willing to provide the needed information. It is not possible to anticipate all of the problems that will be encountered during data collection. Terminologies used in questionnaires or interviews may not be understood by respondents and information to be retrieved from document may not be readily available. Thus, reducing error to the minimum requires the pilot study to test the data collection instrument.

Twenty (20) farmers purposively selected from the New Juabeng District were used for the pilot study. This district was selected due to its nearness to Akim Tafo where the Cocoa Research Institute of Ghana (CRIG) is located. The results of the pilot study led to a modification of a few questions to make them clearer.

Test of reliability and validity of instrument

Golafshani (2003), referencing Joppe (2000), defines reliability as "the extent to which research results are consistent over time" (Joppe 2000, p1). Research instrument is reliable if the results of the study can be reproduced under a similar method. According to Norland (1990), reliability indicates the accuracy or precision of the measuring instrument. Reliability is defined as the extent to which questionnaire; test, observation or any measurement procedure produces the same results on repeated trials. There are three aspects of reliability namely equivalence, stability and internal consistency (homogeneity). Equivalence refers to the amount of agreement between two or more instruments that are administered at nearly the same point in time. Equivalence is measured through a parallel forms procedure in which one administers alternative forms of the same measure to either the same group or different group of respondents.

The second aspect of reliability, stability, occurs when the same or similar scores are obtained with repeated testing with the same respondents. In other words the scores are consistent from one time to the next. Stability is assessed through a test-retest procedure that involves administering the same measurement instrument to the same individual under the same condition after some period of time.

The third aspect of reliability is internal consistency (homogeneity). Internal consistency concerns the extent to which items on the test or instrument are measuring the same thing. Internal consistency gives estimate of the equivalence of sets of items from the same test. The coefficient of internal consistency provides an estimate of the reliability of measurement and is based on the assumption that items measuring the same construct should correlate.

In this study, to test the reliability of the questions in the interview schedule, the services of cocoa extension officers were solicited. They reviewed the questions to ascertain whether they would prompt the type of responses expected. After that a pilot study, the main study was carried out. The data from the pilot study was analysed using SPSS (Statistical Package for Social Sciences). A reliability coefficient of 0.90 was obtained which was good. According to Norland (1990) a reliability coefficient of 0.70 or higher is considered acceptable reliability.

Validity is defined as the extent to which the instrument measures what it purports to measure. There are many different types of validity including content validity, face validity, convergent validity (or discriminant validity). Content validity deals with the degree to which the instrument fully assesses or measures the construct of interest. Face validity is established when an individual reviewing the instrument concludes that it measures the characteristics or truths of interest. Criterion-related validity is assessed when one is interested in determining the relationship of scores on a test to a specific criterion. Construct validity is the degree to which an instrument measures the trait or theoretical construct that it is intended to measure.

Administration of interview schedule for the main study

Extension officers employed by COCOBOD were used to interview the farmers. The extension officers were selected based on recommendation from officers from CRIG who had been working closely with these extension officers. There was a meeting with the selected extension officers at the CRIG training school in Bunso in the Eastern Region in March 2011 to discuss the questionnaire. After the meeting the interview schedules were distributed to the officers. The administration of the interview schedules in the field was between April and July 2011. This period fell within the cocoa light crop season and so farmers had time to listen to the extension officers who used the responses of the farmers to complete the interview schedules. The questions were asked in the local language and so there was the problem of exact translation of the scientific terminologies into the local language. However because cocoa extension officers were used they were able to explain things to the farmers.

The interviews were conducted simultaneously in all the communities by the extension officers. The maximum number of farmers interviewed in a day by each extension officer was five (5). This ensured that they had ample time with each farmer. At the end of each working day, the completed schedules were cross checked to ensure that they were completed well. All uncompleted or doubtful entries were taken back to respondents for clarification and rectification. This was to ensure that the completed schedules did reflect the characteristics, views and opinions of the respondents, thus enhancing the validity and reliability of the instrument.

Data analysis

The assistance of officers in the Ghana Statistical Service was solicited and the information in the completed interview schedules was captured with the use of software called Census and Survey Processing System (CS Pro). The information was then exported to the Stata software for analysis. The descriptive statistics such as mean and standard deviation were obtained using appropriate commands in the Stata software. Also regressions were run using the appropriate commands based on the models to be estimated.

The double hurdle model was used to estimate the determinants of adoption and intensity of adoption whilst ordinary least squares (OLS) was used to estimate the impact of adoption on output.

Explanation of the double hurdle model

The double hurdle model, originated by Cragg (1971), is a parametric generation of the Tobit model in which two separate stochastic processes determine the decision to adopt and level of adoption of technology. The double hurdle model has equations associated with them, incorporating the effects of farmer's characteristics and circumstances. Such explanatory variables may appear in both equations or in either of one. Most importantly a variable appearing in both equations may have opposite effects in the two equations (Langyintuo & Mekuria, 2005).

The first hurdle is a sample selection equation which may be estimated with a probit or logit model. The first hurdle has an adoption (A) equation as in equation 86.

$$\left.\begin{aligned} &A_i = 1 \text{ if } A_i^* > 0 \text{ and } 0 \text{ if } A_i^* \leq 0 \\ &A_i^* = \alpha' Z_i + \mu_i \end{aligned}\right\} \qquad \ldots (86)$$

Where A* is a latent variable that takes the value 1 if the farmer adopts a technology or an innovation and zero, otherwise. Z is a vector of household or farmer characteristics. In this study the first hurdle is estimated with a logit model and it is presented in Chapter Six.

The second hurdle involves an outcome equation which uses a truncated model to determine the extent of adoption (intensity of use) of the technology in question. This second hurdle uses observation only from those respondents who indicated a positive value of use of the technology.

The intensity of adoption (S) is specified as in equation 87.

$$\left.\begin{aligned} &S_i = S_i^* \text{ if } S_i^* > 0 \text{ and } A_i^* > 0 \\ &S_i = 0 \text{ otherwise} \\ &S_i^* = \beta' X_i + v_i \end{aligned}\right\} \qquad \ldots (87)$$

Where S is the intensity of adoption of the technology, X is a vector of explanatory variables hypothesized to influence intensity of technology use, β is a vector of parameters and v_i is the standard error term. The second hurdle is usually a truncated model and may be Tobit model, Poisson regression, geometric or negative binomial. In this study, the Poisson regression is used because of the nature of the data. The intensity of adoption is treated in Chapter Seven.

Empirical results obtained by Moffat (2003) and Martinez-Espineira (2006) indicate that the double hurdle model gives superior results to those obtained from the Tobit model. This explains why the double hurdle is employed in this study to measure adoption and intensity of adoption.

Conclusion

This chapter has dealt with the methodology employed in the study. It looked at the research design which was the survey method used to collect primary data for the study. The population for the study was all cocoa farmers in Ghana which was estimated at 350,000. The study was done in five cocoa growing regions namely: Ashanti, Brong Ahafo, Central, Eastern and Western regions. In all 600 farmers were selected from 10 districts with two districts selected from each region. Also discussed in the chapter are the sample size determination and the sampling procedure. The survey instrument and procedure for data collection were also discussed. Furthermore, there were test of reliability and validity of the instrument used. In Chapter Six, the theoretical and empirical models for the determinants of adoption and discussion of the results are presented whilst Chapters Seven and Eight deal with the theoretical and empirical models and results for intensity of adoption and the impact of adoption on output, respectively.

CHAPTER SIX

DETERMINANTS OF ADOPTION OF COCOA RESEARCH INNOVATIONS IN GHANA

Introduction

This chapter considers the estimation and results of the determinants of adoption of cocoa research innovations in Ghana. The chapter deals with the first objective of the study which is to identify the factors which affect the adoption of cocoa research innovations. It also tests the first hypothesis together with its subdivisions as specified in Chapter One.

The chapter begins with the theoretical model which is based on utility maximization theory. This is followed by a description of the variables in the model and their expected signs. Following immediately after the description of the variables is a presentation of the descriptive statistics on the variables. The chapter continues with a description of the estimation method and discussion of the regression results. It then concludes with a summary of the main findings in the chapter confirming the hypotheses or otherwise.

Theoretical model for determinants of adoption

The theoretical model is presented in chapter four. It will be recalled that the solution of constrained utility maximisation yielded the general technology adoption function as specified in equation 88.

$$A = f(p_q, Q, N, x, \rho, \gamma, p_x, Z, T) \quad (88)$$

Where A is technology adoption and depends on price of the output (p_q), the quantity produced of the commodity (Q), labour (N), quantity of farm input (X), interest rate (ρ), wage rate (γ), price of farm input (p_x), household characteristics and total time available (T). The adoption decision A is a binary one and takes the value 1 if the farmer adopts the technology and zero, otherwise. Prices in the empirical model were omitted because the farmer does not have much influence on them.

Specification of the empirical model for adoption

Based on the theoretical model described in chapter four and literature reviewed in chapter three (3), the empirical model for estimation of determinants of level of adoption is given as equation 89. The equation 89 is the first hurdle under the double hurdle model.

$$\begin{aligned} Adopt &= \beta_0 + \beta_1 Age + \beta_2 hhsize + \beta_3 farmsize + \beta_4 edulev2 \\ &+ \beta_5 edulev3 + \beta_6 edulev4 + \beta_7 edulev5 + \beta_8 credit + \beta_9 hirelab \\ &+ \beta_{10} labour1 + \beta_{11} ownlab + \beta_{12} memasso + \beta_{13} freqadvice + \varepsilon \end{aligned} \quad (89)$$

The expected signs of the coefficients are:

$B_1<0$; $\beta_2>0$; $\beta_3>0$; $\beta_4>0$, $\beta_5>0$, $\beta_6>0$, $\beta_7>0$; $\beta_8>0$; $\beta_9>0$, $\beta_{10}>0$;

$\beta_{11}>0$; $\beta_{12}>0$: $\beta_{13}>0$

Where *Adopt* is level of adoption of cocoa research innovations; *Age* is farmer's age; *hhsize* is household size; *farmsize* is the size of the farm; *edulev2* refers to primary education; *edulev3* is junior secondary/middle school education; *edulev4* is secondary education, *credit* is access to credit; *hirelab* is hired labour; *labour1* is non-hired labour such as spouse labour and reciprocal labour; and *ownlab* refers to farmer's own labour, *memasso* refers to membership of an association and *freqadvice* refers to frequency of extension service advice.

Variables in the model and their expected signs

The dependent variable is adoption which is binary 1 for adoption and 0 for non-adoption. The explanatory variables include the age of the farmer, household size and farm size. Other explanatory variables are education level divided into primary, junior secondary school (JSS) / Middle school, senior secondary school (SSS) /Technical/training college and tertiary education. The remaining explanatory variables are credit, hired labour, non-hired labour (such as casual labour, reciprocal labour and spouse labour) and farmer's own labour.

Age of the farmer or head of household

The role of a farmer's age in explaining technology adoption is somewhat controversial in literature. Older people are sometimes thought to be less amenable to change and hence reluctant to change their old ways of doing things. It may be that older farmers are more risk averse and less likely to be flexible than younger farmers and thus have a lesser likelihood of adopting new technologies. In this case, age will have a negative impact on adoption. However, it could also be that older farmers have more experience in farming and are better able to assess the characteristics of modern technology than younger farmers, and hence a higher probability of adopting the practice.

Adesina and Baidu-Forson (1995) indicated that the expected result of age is an empirical question. There is no agreement in the adoption literature on this as the direction of the effect is generally location or technology specific. In this study, however, the a priori sign for the impact of age on adoption and intensity of adoption was postulated to be negative in line with Forster and Stem (1979), Ervin (1982) and Norris and Batie (1987) who found that older farmers are less likely to use new technology because of their shorter planning horizons and less than perfect capitalization of yield changes in land prices.

Household size

Household is defined as all the people living together in a house. The people living in the house may be the farmer, his or her spouse, biological children and other members of the extended family. There is no agreement in adoption literature as regard the direction of influence of household size on technology adoption. Manyong and Houndekon (1997) postulated household size to be positively related to technology adoption decisions while Owu (1995) claimed the variable had a negative relationship with adoption.

In situations where a greater number of the people living in the house are minors, aged or invalid, a bigger household size will negatively affect adoption as the labour from the family will be low. It is expected in this study that a larger household size will positively influence the decision of acceptance because of the availability of labour required during the adoption process.

Farm size

According to Langyintuo and Mekuria (2005), the size of the family farm is a factor that is often argued as important in affecting adoption decisions. It is frequently argued that farmers with larger farms are more likely to adopt an improved technology (especially modern varieties) compared with those with small farmers as they can afford to devote part of their fields (sometimes the less productive parts) to try out the improved technology.

Langyintuo and Mekuria (2005) further believe that the directional effect of farm size on adoption is contradictory. For example, what may be showing up as the effect of farm size may be due to credit, labour availability, among others. Understanding the relative roles of these variables is facilitated by adequate knowledge of the study area. In this study, it is hypothesised that farm size will positively affect adoption and intensity of adoption to agree with the position of Norris and Batie (1987), Kebede, Gunjal and Coffin (1990) and Polson and Spencer (1991).

Level of education

The farmer's level of education is a human capital variable used as a proxy to indicate the ability to acquire and process information (Damianos and Kuras 1996; Faturoti et al, 2006). It is often assumed that educated farmers are better able to process information and search for appropriate technologies to alleviate their production constraints. The belief is that education gives farmers the ability to perceive, interpret and respond to new information much faster than their counterparts without education. But it is often the case in many countries that the majority of farmers are illiterate.

Education augments one's ability to receive, decode and understand information relevant to making innovative decisions (Wozniak 1984). Farmers with more education should be aware of more sources of information, and be more efficient in evaluating and interpreting information about innovations than those with less education. Thus, it is hypothesized in this study that farmers with more education are more likely to be adopters and intensify their adoption than farmers with less education. This proposition agrees with Boahene (1995), Legese et al (2009), Langyintuo and Mekuria (2005). Ben-Houassa (2011) and Aneani et al (2012).

Credit access

The lack of sufficient accumulated savings by smallholder farmers prevents them from having the necessary capital for investing in new technologies. According to Just and Zilberman (1983), Boahene et al (1999) and Teklewood et al (2006) the availability of credit may positively influence adoption of technology by relaxing the binding capital constraints that farmers face during initial investments or helps to finance the variable costs associated with production. On the other hand, a number of scholars such as Schutjer and Veen (1977) have argued that lack of credit does not inhibit adoption of innovations that are scale neutral.

In this study, access to credit was defined as farmers who obtained loan from a financial institution and other sources such as LBCs and non-bank financial institutions for their farming operations. It is expected that availability of credit will positively influence adoption and intensity of adoption of cocoa research innovations to agree with the position of Boahene et al (1999).

Availability of labour

According to the Ministry of Manpower, Youth and Employment (MMYE, 2007), cocoa production, particularly under the small holder system as occurs in Ghana, is highly labour intensive. It begins with land preparation for establishing the cocoa farm, including felling of trees, slashing of the vegetative cover, burning of the bush and clearing of debris, among others. Farmers use a combination of own labour, family labour, hired labour, and reciprocal or communal (nnoboa) labour in cocoa production. Although the farm owners contribute their own labour, hired labourers are often used to provide some of these services.

The amount of hired labour that the farmer can use depends on the specific tasks to be performed, resources available to the farmer to hire labour and the utility of hiring. It is expected in this study that hired labour will positively affect adoption and intensity of adoption because it will make labour available. This agrees with the proposition of Ben-Houssa (2011) and Aneani et al (2011) who postulated a positive relationship between hired labour and technology adoption.

Non-hired labour

Non-hired labour is made up of farm hand for which the farmer does not pay wages or salaries. They include reciprocal or communal labour.

Reciprocal or communal or cooperative labour refers the situation where farmers offer their services in turns on respective farms without taking any wage. A number of farmers may come together to form such a group and work on the farms of each farmer in turns. Members of the group are not paid for the services rendered. Each farmer is expected to feed the workers on the day that work is done on his farm. It is expected in this study that there will be a positive relationship between non-hired labour and the level of adoption of cocoa research innovations. This proposition agrees with Boahene (1995) who postulated a positive relationship between adoption of hybrid cocoa and farmers' access to cooperative labour.

Own labour

This is labour provided by the farmer himself. Factors which determine the utilisation of own labour includes the health of the farmer, awareness on the part of the farmer, and influence of services advocates and opinion management. It may also depend on copy-cut environment and reaction and ready to catch the new spirit. It is expected in this study that own labour will positively affect adoption of adoption of cocoa research innovations. This proposition agrees with Hicks and Johnson (1974) who believe that availability of rural labour supply in terms of own labour leads to greater adoption of labour intensive rice varieties in Taiwan.

Membership of an association

Membership of an association refers to farmers joining societies or clubs or associations where issues on cocoa are discussed. According to

Langyintuo and Mekuria (2005) in most farming communities, farmers form or join associations or cooperatives of various kinds for all sorts of reasons. Such associations or cooperatives sometimes afford farmers the opportunity to have better access to information, which is an important condition for adopting an improved technology. Some financial institutions are prepared to lend credit to farmers only when they are in an association or cooperative. Therefore belonging to an association or cooperative can influence a farmer's decision to adopt an improved technology which may impact on the output. Membership of association was measured with a dummy variable. In this study it was expected that there would be a positive relationship between membership of association and level of technology adoption.

Frequency of extension service advice

Frequency of advice from extension officers measured the number of times farmers received advice from extension officers in a year. According to Baah and Anchirinah (2011), extension as an activity is traditionally viewed as a means of transmitting knowledge to farmers by extension institutions. Extension activities are not the preserve of extension institutions alone. Research institutes including the Cocoa Research Institute of Ghana have the responsibility to not only develop technologies for clientele but also share information and knowledge about the technologies with them in an interactive manner. The study postulated that there would be a positive relationship between frequency of advice from extension officers and level of technology adoption.

Estimation method for determinants of adoption

According to Gujarati and Porter (2009), there are three methods of parameter estimation. These are least squares, maximum likelihood and methods of moments. The maximum likelihood estimation is employed for the estimation of the determinants of adoption. The method of maximum likelihood, as the name indicates, consists in estimating the unknown parameters in such a manner that the probability of observing the given dependent variable is as high as possible.

The model in equation 89 was estimated using the first hurdle under the double hurdle model proposed by Cragg (1971). A detailed explanation of the double hurdle model is provided in the literature review and in Chapter Five. In this study, the first hurdle which dealt with adoption decision was estimated by logit because of the nature of the data set. It is also due to the fact that logit model is able to handle cases of a dependent variable with more than two categories as compared to the probit model which deals with dependent variables with only two categories. The syntax used in stata was:

hplogit [dependent variable] [independent variables], robust

Measurement of variables in the model

The descriptive statistics of the variables used in the study of the determinants of level of adoption of cocoa research innovations are presented in Table 7. They show the number of observations, their mean values, standard deviation among others.

Table 7: Descriptive statistics for variables

Variable	Description	Obs.	Mean	S. dev	Min	Max
Adopt	Level of Adoption	600	0.68	0.47	0	1
Output	Cocoa output in Kg	600	771.67	298.48	188	1875
lnyield	Log of Output	600	6.57	0.40	5.24	7.54
Age	Age of farmer (years)	600	50.12	11.40	22	72
Hhsize	Household size	600	4.53	0.73	2	7
Farmsize	Farm size in Acres	600	4.90	1.15	2	10
edulev1	No formal Education (1/0)	130	0.22	0.41	0	1
edulev2	Primary education(1/0)	116	0.19	0.39	0	1
edulev3	JSS/Middle School(1/0)	302	0.50	0.50	0	1
edulev4	SSS/Technical/ Trg. Coll(1/0)	48	0.08	0.27	0	1
edulev5	Tertiary (1/0)	4	0.01	0.081	0	1
Credit	Credit Access(1/0)	600	1.29	0.46	0	1
Hirelab	Hired labour	600	3.74	1.41	0	9
Labour1	Non-Hired Labour	600	2.93	2.30	0	8
Ownlab	Own labour(1/0)	600	0.66	0.47	0	1

Source: Fieldwork, 2011

Note: No education is used as the reference category for education.

Test for multicollinearity

Multicollinearity refers to the existence of a perfect or exact or approximately exact linear relationship among some or all explanatory variables of a regression model. (Gujarati and Porter, 2009). In this study multicollinearity was tested using the correlation matrix. Under this technique, it is expected that the existence of high zero-order correlations are a sufficient but not a necessary condition for the existence of multicollinearity. The correlation matrix for the variables used in the model is presented in Appendix I. It shows that there was no multicollinearity.

Frequency distribution of variables

The frequency distributions for the main variables used are presented under their respective headings. Variables considered in the study are the age of the farmer, household size, farm size, educational level, credit access, hired labour, non-hired labour and own labour.

Age of the farmer

The age of the farmer determines whether the farmer is a youth or an aged. It is generally believed that the youth are more energetic and as such are able to perform more strenuous work. Table 8 shows the frequency distribution of the age of farmers. The majority (53%) of the farmers were between the ages 41 and 50 years and the average age was 50.12 years. This suggests that most of the farmers are of middle age. This finding is consistent with finding of Boahene (1995) who had the average age of farmers as 53 years.

Table 8: Frequency distribution for age of farmers

Age	Frequency	Percent	Cumulative%
21-20	18	3.0	3.0
31-40	120	20.0	23.0
41-50	180	30.0	53.0
51-60	170	28.3	81.3
61-70	97	16.2	97.5
71-80	15	2.5	100.0
Total	600	100.0	

Source: Fieldwork, 2011

Household size

Table 9 is a presentation of the frequency distribution for household size used in the study.

Table 9: Frequency distribution for household size

Number	Frequency	Percent	Cumulative %
2	2	0.33	0.33
3	34	5.67	6.00
4	249	41.50	47.50
5	277	46.17	93.67
6	34	5.67	99.33
7	4	0.67	100.00
Total	600	100.00	

Source: Fieldwork, 2011

The size of the household ranges from 2 to 7 and the average was 4.53 (approximately 5 people). 46.2 per cent of the respondents had household size of five (5). This finding is consistent with what is contained in the Round Five (5) of the Ghana Living Standard Survey (2008).

Farm size

The frequency distribution for farm size is presented in Table 10. About 57.8% of the farmers had farm sizes between 1 and 10 acres and the average farm size was 13.17 acres. The farm sizes conform to the general characteristics of cocoa farmers who are basically small holders. The farmers do not usually have large plantations. In the past the government used to have large plantations but these were sold to individual farmers and companies.

Table 10: Frequency distribution for total farm size in acres

Acreage	Frequency	Percent	Cumulative %
2	9	1.5	1.5
3	22	3.7	5.2
4	153	25.5	30.7
5	338	56.3	87.0
6	42	7.0	94.0
7	6	1.0	95.9
8	19	3.2	98.2
9	4	0.7	98.8
10	7	1.2	100.0
Total	600	100.0	

Source: Fieldwork, 2011

Level of education

Level of education was categorised into no education, primary education, middle school/junior secondary school education, senior secondary school education and tertiary education. The majority of the farmers (50.3%) had middle school or junior secondary school education. Those who had tertiary education were less than 1%. The frequency distribution for level of education is presented in Table 11.

Table 11: Frequency distribution for educational level

Level	Frequency	Percent	Cumulative %
No formal education	130	21.7	21.7
Primary Education	116	19.3	41.0
Middle School/JSS	302	50.3	91.3
Secondary School	48	8.0	99.3
Tertiary	4	0.7	100.0
Total	600	100.0	

Source: Fieldwork, 2011

Credit access

Frequency distribution for credit access is presented in Table 12. It is a summary of the responses of farmers with regards to the funding of their operations from borrowing either from financial institutions or non-bank financial institutions. About Seventy one (71) per cent of the respondents had no access to credit.

Table 12: Frequency distribution for credit access

Access	Frequency	Percent	Cumulative %
No	423	70.5	70.5
Yes	177	29.5	100.0
Total	600	100.0	

Source: Fieldwork, 2011

Hired labour

This refers to labourers who are paid to work on the farm. They may be casual labourers or permanent labourers. Table 13 shows the frequency distribution of hired labour. The most frequent number of labourers hired by farmers is 3.

Table 13: Frequency distribution for hired labour

Number	Frequency	Percent	Cumulative %
0	1	0.17	0.17
1	25	4.17	4.33
2	103	17.17	21.50
3	173	28.83	50.33
4	139	23.17	73.50
5	76	12.67	86.17
6	39	6.50	92.67
7	30	5.00	97.67
8	13	2.17	99.83
9	1	0.17	100.00
Total	600	100.00	

Source: Fieldwork, 2011

Non-hired labour

Non-hired labour refers to the engagement of services of people who are not paid any wage on the farm. They usually include friends or members of a cooperative group who visit the farms of members on rotational basis to assist each of the members in the group perform certain activities such as weeding, plucking of cocoa and breaking the pods. Table 14 shows the frequency distribution of non-hired labour. About 28.67% of the respondents engaged 2 non-hired labourers each on their farms.

Table 14: Frequency distribution for non-hired labour

Number	Frequency	Percent	Cumulative %
0	2	0.33	0.33
1	82	13.67	14.00
2	172	28.67	42.67
3	162	27.00	69.67
4	109	18.17	87.83
5	46	7.67	95.50
6	14	2.33	97.83
7	8	1.33	99.17
8	5	0.83	100.00
Total	600	100.00	

Source: Fieldwork, 2011

Own labour

The frequency distribution for own labour is presented in Table 15 and it shows that about 66.2% of the respondents used their own labour.

Table 15: Frequency distribution for own labour

Access	Frequency	Percent	Cumulative %
Yes	203	33.8	33.8
No	397	66.2	100.0
Total	600	100.0	

Source: Fieldwork, 2011

Membership of association

A greater percentage of the respondents (57.17%) indicated that they belonged to cocoa producer association such as the Cocoa Abrabopa Association or Kuapa Kookoo Farmers Association. In such associations members are taught how to cultivate cocoa and discuss pertinent issues bordering on the production of the crop. Frequency distribution for membership of an association is shown in Table 16.

Table 16: Frequency distribution of membership of association

Membership	Freq.	Percent	Cumulative
No	257	42.83	42.83
Yes	343	57.17	100.00
Total	600	100.00	

Source: Fieldwork, 2011

Frequency of extension advice

About 33.5% of the respondents indicated that they were visited at least once a month by extension officers. These extension officers were from the Ministry of Food and Agriculture or COCOBOD. They usually provided advisory services on how to handle a particular problem such as fertilizer application or proper management of disease and pests on the farm. Frequency distribution for visit by extension officers is shown in Table 17 it can be deduced from the table at up to about 76.5 per cent of the respondents were visited at least once a month. Those who are not visited at all form about 14.5 per cent of the respondents.

Table 17: Frequency distribution of number of extension visits

Number of Times	Freq.	Percent	Cumulative
No visit	87	14.50	14.50
Once a week	130	23.67	36.17
Once every fortnight	116	19.33	55.50
Once a month	201	33.50	89.00
Once every six months	48	8.00	97.00
Once a Year	12	2.00	99.00
Other	6	1.00	100.00
Total	600	100.00	

Source: Fieldwork 2011

Result of the estimation of determinants of adoption

The results of the determinants of adoption of cocoa research innovations are presented in Table 18. The log likelihood estimate of -350.72 with a statistically significant chi-square of 18.11 indicated that the explanatory variables jointly determined the adoption decision of cocoa farmers. The pseudo R-square was estimated to be 0.3347 indicating that about 33.5 per cent of the variation in the dependent variable was explained jointly by the predictors.

Table 18: Estimated results of first hurdle (Logit Regression) for determinants of adoption

Adopt	Coefficient	Standard Error	Robust Standard Error
Age	-0.134**	0.0497	0.0533
Hhsize	0.3225*	0.15207	0.1069
Farmsize	0.2431*	0.10580	0.1024
edulev2	0.9442**	0.3878	0.4480
edulev3	0.2990	0.2976	0.2620
edulev4	-0.0412	0.4497	0.4180
Edulev5	0.0437	0.4286	0.4067
Credit	2.811***	0.7570	0.6580
Hirelab	1.648**	0.7130	0.6710
NonHired lab	-1.630**	0.7180	0.6860
Ownlab	4.250***	1.3030	1.4370
Memasso	1.3451**	0.2442	0.2532
Freqadvice	0.30162***	0.0934	0.1046
Constant	2.691	3.1370	3.0080

Source: Regression results based on Fieldwork, 2011

Notes: Robust estimation corrects for Heteroscedasticity detected.

*** = significant at 1%; ** = significant at 5%; * = significant at 10%

Number of observations 600; Wald chi square (12) = 18.11; Pseudo R^2 = 0.3347; Prob > chi square = 0.2017

Discussion of the results of determinants of adoption

A discussion of the results from the estimation of the first hurdle model is presented in this section. The discussion is on only the variables which were statistically significant in explaining the adoption behaviour of the cocoa farmers.

Age of the farmer

The coefficient of the age variable is given as -0.134. This means for a one year increase in the age of the farmer, we expect a 0.134 decrease in the log-odds of adoption, holding other variables constant. Thus an increase in the age of the farmer reduces the probability of adoption of cocoa research innovation. This result agrees with most studies reviewed (Donkoh, 2006; Abera, 2008) and consistent with the stated hypothesis. As farmers grow older, they tend to be more conservative and risk averse compared to younger farmers. Young farmers who are vibrant, energetic and innovative may be prepared to allocate resources to new technologies, other things being equal.

Household size

The coefficient of household size was 0.3225 and significant at 10 per cent. Thus an increase in the size of household by one is expected to increase the log-odds of adoption by 0.3225, other things being equal. The results show that there is a positive relationship between household size and adoption of cocoa research innovations and agrees with the stated hypothesis. This finding corroborates those of Manyong and Houndekon (1997).

Farm size

There was a positive relationship between the farm size and adoption of cocoa research innovation. The coefficient for farm size was 0.2431 and significant at 10 per cent. This indicates that an increase in the farm size by an acre is likely to result in an increase in the log-odds of adoption by 0.2431. The positive relationship between farm size and adoption confirms the stated hypothesis and the finding of Norris and Batie (1987), Kebede et al (1990) and Spencer (1991).

Education

As explained earlier, education was divided into no education, primary education, junior secondary or middle school, secondary or technical education and tertiary education with no education as the reference category. It was primary education which was significant at 1 per cent with a coefficient of 0.94423. This indicated that primary education has a positive impact on farmers' decision to adopt cocoa research innovation. Thus, respondents with primary education have a higher probability of adoption of cocoa research innovations than those with no formal education. The positive relationship between education and adoption agrees with the stated hypothesis and the findings of Boahene (1995), Legese et al (2009), Langyintuo and Mekuria (2005), Ben-Houssa (2011) and Aneani et al (2012).

Credit access

The coefficient of credit access is 1.5611 and is significant at 1%. This means a unit increase in credit access will result in 1.5611 increase in the log-odds of adoption, holding other variables constant. This suggests that Credit access has a positive impact on the adoption of cocoa research innovation and confirms the stated hypothesis. By this finding therefore, respondents who received credit have higher probability of adoption of cocoa research innovation than those who did not receive credit. This result agrees with most studies reviewed. (Donkoh, 2006; Boahene, 1995). Even though the percentage of respondents who accessed credit was small, the finding is significant and confirms the findings of other researchers that credit constraint is an important determinant of technology adoption.

Hired labour

Hired labour had a coefficient of 1.648 and was significant at 5%. This implies an increase in the number of hired labour by one will other things being equal, lead to a 1.648 increase in the log-odds of adoption. This may be due to the fact that hired labourers provided the needed manpower required for the use of modern method of cocoa production as recommended under the high technology package. The finding is in conformity with the stated hypothesis and with Boahene's (1995) position that hired labour is a significant variable that determines the adoption of technology.

Non-hired labour

The coefficient for non-hired labour was -1.630 and was significant at 5%. This means an increase in non-hired labour by one will lead to a reduction in the log-odds of adoption by -1.630. There was therefore a negative relationship between non-hired labour and decision to adopt cocoa research innovations. It is worth recapping that non-hired labour included spouse labour and reciprocal labour. This finding is contrary to the stated hypothesis and the finding of Boahene (1995) who observed a positive relationship between adoption of hybrid cocoa and farmers' access to cooperative labour. The possible reason for this finding may be that the non-hired labour did not have the required skills for the job.

Own labour

The coefficient of own labour is 4.250 and significant at 1%. The result indicates that a unit increase in own labour will lead to 4.250 increase in the log-odds of adoption of cocoa research innovations, other things being equal. This suggested a positive relationship between own labour and adoption of cocoa research innovations. The finding confirms the stated hypothesis and agrees with Hicks and Johnson (1974) who believe that own labour leads to greater adoption of labour intensive rice varieties in Taiwan.

Membership of an association

The coefficient for membership of an association is 1.3451 and significant at 1 per cent. This indicates that a unit increase in membership will lead to a 1.3451 increase in the log-odds of adoption of cocoa research innovations, other things being equal. Thus, there is a positive relationship between membership of an association and adoption of cocoa research innovations, a confirmation of the stated hypothesis. This finding agrees with that of Opoku et al (2009) who found that members of the Cocoa Abrabopa Association adopted the Hitech programme.

Frequency of extension advice

Results of the study indicated that there was a positive relationship between frequency of extension advice and the level of adoption of cocoa research innovations. The coefficient of frequency of extension advice was 0.301 implying a unit increase in extension advice will lead to a in the log-odds of adoption of cocoa research innovations, other things being equal. This finding confirms the stated hypothesis and agrees with Baah (2011) that there is a positive relationship between extension advice and adoption of technology.

Conclusion

This chapter estimated the determinants of adoption of cocoa research innovation in Ghana. Thus, it dealt with the first objective of the study which was to identify the factors which affect the adoption of cocoa research innovations. The double hurdle model was used for the estimation of the empirical model and the results confirmed the first hypothesis. Age of the farmer and non-hired labour had negative relationship with adoption of cocoa research innovation. Also, household size, hired labour, own labour, farm size, membership of an association, access to credit, frequency of extension advice and education had positive relationship with adoption of cocoa research innovations. Thus results from the study indicate that the major determinants of adoption of cocoa research innovations are: age of the farmer, non-hired labour, household size, hired labour, own labour, farm size, membership of an association, access to credit, frequency of extension advice and education.

CHAPTER SEVEN

DETERMINANTS OF INTENSITY OF ADOPTION OF COCOA RESEARCH INNOVATIONS

Introduction

In the previous chapter, there was a discussion on the determinants of adoption of cocoa research innovations. After a farmer has taken a decision to adopt a technology, the next concern is the degree or extent to which he/she adopts the technology. It is worth noting that the decision to adopt a technology and intensity of adoption may be taken simultaneously. This chapter attempts to deal with the second objective of the study which is to identify the factors which determine the intensity of adoption of cocoa research innovations in Ghana. Also, the chapter enables us to find answers to the second hypotheses under the second model for the study.

The theoretical basis for the intensity of adoption is the utility maximization explained in Chapter Four. Both adoption and intensity of adoption are based on utility maximisation under the agricultural household model. This chapter begins with the specification of the empirical model for intensity of adoption. This is followed by explanation of the variables and their expected signs and then discussion of the main findings from the estimation. The chapter ends with a summary of the main findings.

Empirical model for determinants of intensity of adoption

Based on the theoretical model described in Chapter Four and the literature reviewed in Chapter Three, the empirical model for estimation of the determinants of intensity of adoption is given as follows:

$$\begin{aligned} Adopt\,intense &= \beta_0 + \beta_1 Age + \beta_2 hhsize + \beta_3 farmsize + \beta_4 edulev2 \\ &+ \beta_5 edulev3 + \beta_6 edulev4 + \beta_7 edulev5 + \beta_8 credit + \beta_9 hirelab + \beta_{10} labour1 \\ &+ \beta_{11} ownlab + \beta_{12} memasso + \beta_{13} freqadvice + \varepsilon \end{aligned} \quad (90)$$

The expected signs of the coefficients are:

$B_1<0$; $\beta_2>0$; $\beta_3>0$; $\beta_4>0$; $\beta_5>0$; $\beta_6>0$, $\beta_7>0$; $\beta_8>0$; $\beta_9>0$; $\beta_{10}>0$; $\beta_{11}>0$; $\beta_{12}>0$; $\beta_{13}>0$

Where *Adoptintense* is intensity of adoption of cocoa research innovations; *Age* is farmer's age; *hhsize* is household size; *farmsize* is the size of the farm; *edulev2* refers to primary education; *edulev3* is junior secondary/middle school education; *edulev4* is secondary education, *credit* is access to credit; *hirelab* is hired labour; *labour1* is non-hired labour such as spouse labour and reciprocal labour; and *ownlab* refers to farmer's own labour. *memasso* refers to membership of an association, *freqadvice* refers to frequency of extension advice and ε is the error term.

Variables included in the model and their expected signs

With exception of intensity of adoption which is explained below, all the other variables and their expected signs are as described in Chapter Six. The explanations of the other variables have not been repeated so as not to make the presentation monotonous.

Intensity of adoption

Intensity of adoption measures the degree or extent of adoption of a technology. Intensity of adoption has been measured in several ways in literature. Nkonya, Schroeder and Norman (1997) measured the intensity of adoption as the number of hectares planted with improved seed or the amount of input applied per hectare. Mensah-Bonsu, Sarpong, Alhassan, Asuming-Brempong, Egyir, Kuwornu and Osei (2011); Paxton, Mishra, Chintawa, Roberts, Larson, English, Lambart, Marra, Larkin, Reeves and Martin (2011); and Masuki, Mutabazi, Tumbo, Rwehumbiza, Mattee and Hitabu (2006) defined intensity as the number of technologies adopted. Other researchers such as Kaguongo, Ortmann, Wale, Darroch and Low (2010); Nchida, Ambe, Nathalie, Leke, Che, Nkwate, Ngassam and Njualem (2010); and Asfaw, Shiferaw, Simtowe and Haile (2011) defined intensity of adoption as the proportion of area under the improved varieties.

In this study intensity of adoption is measured following the example of Opare (1980) using a scale 1 to 5. Farmers ranked the intensity of adoption of the various cultural practices such as weeding, spraying insecticides, fertilizer application, among others, as follow: very low (1), low (2), moderate (3), high (4) and very high (5). This scale was used in computing the intensity of adoption of a particular cultural practice and the result was expressed as a percentage.

Table 19 presents explanation of how the computation was done. In the example, there are three cultural practices namely weeding, spraying of insecticides and fertilizer application. Also, there are four farmers namely A, B, C and D. The maximum mark for each of the cultural practices is 5 and a total of 15 for all the three practices. Thus, farmer A's intensity of adoption of all the three practices is 47 percent (which is the total score of 7 divided by the maximum score of 15). To determine the intensity of adoption of a particular cultural practice by all the farmers, there should be a vertical summation of all the marks by the respective farmers divided by the maximum score. In the example, the intensity of adoption of weeding, spraying and fertilizer application were 55%, 50% and 65% respectively. The actual computation for the whole 600 farmers has not been provided here in view of the volume it involves.

Table 19: Computation of intensity of adoption

Farmer	Weeding	Spraying	Fertilizer	Total	Max Score	Intensity %
A	2	2	3	7	15	47
B	3	1	3	7	15	47
C	3	3	3	9	15	60
D	3	4	3	10	15	67
Total	11	10	13	33	60	55
Max Score	20	20	20	60		
Intensity %	55	50	65	55		

In Table 19 the total in the fifth column is a summation of the values in columns 2, 3 and 4. The maximum score in the 6th column is obtained by multiplying the three practices by the maximum score of five (i.e. 3 x 5 = 15). From the sample of 600 used for the study, the results obtained for intensity of adoption were 53.1%, 48.9%, 46.1%, 46.2%, and 56.4% for weeding, spraying, fertilizer application, fungicide application, fermentation and drying of cocoa respectively. In this study, Intensity of adoption is expected to positively affect output.

The frequency distribution for intensity of adoption is shown in Table 20. It shows that 28.8% did not adopt any of the technologies. Of those who adopted, the intensity ranges between 1 per cent and 100 per cent.

Table 20: Frequency distribution for intensity of adoption

Intensity (%)	Frequency	Percent	Cumulative.
0	173	28.8	28.8
1-10	1	0.2	29.0
11-20	4	0.7	29.7
21-30	5	0.8	30.5
31-40	10	1.7	32.2
41-50	18	3.0	35.2
51-60	58	9.7	44.9
61-70	85	14.2	59.1
71-80	137	22.8	81.9
81-90	62	10.3	92.2
91-100	47	7.8	100.0
Total	600	100.0	

Source: Fieldwork, 2011

About 137 farmers representing 22.8 percent of the respondents' intensity of adoption of the cultural practices was between 71 and 80 per cent.

The mean intensity of adoption was 50.63 per cent with a standard deviation of 35.14 per cent.

Estimation method for intensity of adoption

The model for determinants of intensity of adoption of cocoa research innovation was estimated with maximum likelihood estimation using the Poisson regression which was the second method under the double hurdle model. It is worth recapping that under the double hurdle model, two separate stochastic processes determine the decision to adopt and the extent or intensity of adoption. The intensity of adoption deal with the non-zero observations that takes on continuous positive values in the data set and hence the use of truncated regression in the form of Poisson regression to handle the model. The coefficients are therefore the estimated Poisson regression coefficients for the model. A coefficient indicates that for a unit change in the predictor variable, the difference in the logs of expected counts is expected to change by the respective regression coefficient, given the other predictor variable in the model are held constant.

Alternatively, two step Heckman model could also be applied for the estimation of the intensity of adoption. The Heckman two-step method also known as the heckit procedure, Heckman lambda or Heckman correction model is due to Heckman (1976). In the first step, we estimate the probability of adoption using a probit model. In the second step the inverse Mills ratio or the hazard rate that is derived from the probit model is added to the variables in the probit model and estimated. The Heckman two step model was not used for the study because they are not as efficient as the maximum likelihood (ML) estimates.

The Heckman correction takes place in two stages. In the first stage the researcher formulates a decision model based on economic theory. Then the inverse Mills ratio which is the ratio of the probability density function to the cumulative distribution function is computed. In the second stage, the inverse Mills ratio is used as an additional explanatory variable.

The difference between the Heckman model and the Cragg double hurdle model revolve around the assumptions about the farmer's decision at the two stages of the model and whether the decisions can be made simultaneously or not. In the Heckman two step method decision to adopt and intensity of adoption are made sequentially whereas in the Cragg double hurdle model the decision to adopt and intensity of adoption are taken simultaneously. The Cragg double hurdle model is more flexible of the two stage models as it allows for censoring at either stage of the model. Also, results of the double hurdle model have been found to be superior to the other models and that explained why the model was used in this study. The model was estimated with the stata command *hplogit*.

Measurement of variables in the model

The descriptive statistics for the intensity of adoption model are the same as those in Table 6 in Chapter Six because the explanatory variables are the same. Also, the frequency distributions of the variables are the same as those in Chapter Six and so they are not repeated in this chapter.

Results of the estimation of intensity of adoption

The second hurdle (Poisson regression) results are presented in Table 21.

Table 21: Estimated results of second hurdle (Poisson Regression) for determinants of intensity of adoption

Adoptintense	Coefficient	Standard Error	Robust St. Error
Age	0.00045***	0.00005	0.00010
Hhsize	0.01764***	0.00772	0.00160
Farmsize	0.01125***	0.00469	0.00410
edulev2	0.00587**	0.01759	0.00235
edulev3	0.04344***	0.01541	0.01915
edulev4	0.01521	0.02407	0.04453
Edulev5	0.16949	0.20497	0.19437
Credit	0.00554***	0.00144	0.00254
Hirelab	0.02459***	0.00368	0.00623
Nonhirelab	-0.03326***	0.00425	0.00845
Ownlab	0.00644***	0.01368	0.02779
Memasso	0.02767**	0.01158	0.01199
Freqadvice	0.03415***	0.00583	0.01067
Constant	4.1589***	0.09564	0.10611

Source: Regression results based on Fieldwork, 2011.

Notes: Robust estimation corrects for Heteroscedasticity detected.

*** = Significant at 1% ; ** = Significant at 5% ; * = Significant at 10%

No. of obs = 600; Log Likelihood = -2403.2186; Wald chi^2 (12) =103.84;

Prob > chi square = 0.0145; Pseudo R^2 = 0.2139

Discussion of results for determinants of intensity of adoption

The log likelihood estimate of -2403.22 with statistically significant chi-square of 103.84 indicated that the explanatory variables jointly determined the intensity of adoption of cocoa research innovations. The pseudo R-square of 0.2139 implied that about 21.39 per cent of the variation in the dependent variable was explained jointly by the predictors.

Age of the farmer (household head)

The age of household head had a coefficient of 0.00045 and was significant at 1%. This means if the age of household head were to increase by one year, the difference in the logs of expected counts would be expected to increase by 0.00045 while holding the other variables in the model constant. Thus age had significant and positive influence on intensity of adoption of cocoa research innovations. The finding is consistent with that of Maddison (2006), Nhemachena and Hassan (2007) and Ashenafi (2007) who argue that as farmers get older they tend to intensify the adoption of new technologies in their farming business as a result of more years of farming experience, higher capital accumulation and large family sizes as a source of family labour. The possible explanation for this is that older farmers intensify the use of the technology once they are convinced of its usage. In other words, older farmers will tend to stick to a particular technology for a long time and intensify its usage. This finding is in contrast with the hypothesis and the finding of Langyintuo and Mulegetta (2005) and Baidu-Forson (1999) who had a negative relationship between age and intensity of adoption.

Household size

The coefficient of household size is 0.01764 and significant at 1% implying an increase in household size by one is expected to increase the difference in the logs of expected counts by 0.01764, while holding other variables in the model constant. Thus, household size had a positive and statistically significant impact on the intensity of adoption of cocoa research innovation. The finding agrees with the stated hypothesis and the findings of Doss (2006) and Manyong and Houndekon (1997) who found household size to be positively related to intensity of adoption of technology.

Farm size

Farm size has a positive and significant impact on the intensity of adoption of cocoa research innovations. The coefficient for farm size was 0.01125 and significant at 1%. This means an acre increase in farm size will result in an increase in the difference in the logs of expected counts by 0.01125, other things being equal. Thus, the finding confirms the stated hypothesis which postulated a positive relationship between farm size and intensity of adoption. The finding agrees with Abera (2008) who found positive relationship between intensity of herbicides use and farm size. A possible explanation for the positive relationship between farm size and intensity of adoption of cocoa research innovations is that, other things being equal, the farmer will get higher output and income from a large farm than a small farm. Part of this income can be used to acquire greater quantities of the needed inputs for the adoption of the new technology.

Education

The coefficients for primary education, middle school/junior secondary school education and senior secondary school education were 0.00587, 0.04344 and 0.001521, respectively. Primary education and middle school/ junior secondary school education were significant at 5 per cent. However, senior secondary school was not significant.

The findings indicate that intensity of adoption of cocoa research innovation by farmers who have primary and middle school or junior secondary was positive. This implies that farmers with some level of formal education were able to adopt agricultural technologies as compared to farmers without any level of formal education. The finding agrees with those of Weir and Knight (2000), Forster and Roseweig (1996), Forster and Stem (1979), Ervin and Ervin (1982), Oluyole (2005) and Ben-Houssa (2011). Thus, the hypothesis that there is a positive relationship between education and intensity of adoption of cocoa research innovations is partially confirmed.

Credit access

The coefficient of credit access is 0.00554 and significant at 1%. This means the difference in the logs of expected counts for intensity of adoption is expected to increase by 0.00554, other things being equal. Thus, credit access had a positive and significant influence on the intensity of adoption of cocoa research innovations. The finding confirms the hypothesis and the finding of Techane, Demeke and Emana (2006) that had a positive and significant influence of credit on the intensity of adoption of fertilizer use on cereal.

Hired labour

Hired labour had a positive and significant impact on the intensity of adoption of cocoa research innovations. The coefficient of hired labour was 0.02459 implying that an increase in hired labour by one unit will increase the difference in the logs of expected counts by 0.02459, holding other variables constant. Thus, hired labour made it possible for the farmer to get the required labour for adopting the cocoa research innovations. The finding agrees with the stated hypothesis and those of Ben-Houassa (2011) and Aneani, Anchiranah, Owusu-Ansah and Asamoah (2012) who observed that availability of hired labour positively affected intensity of technology adoption.

Non-hired labour

Non-hired labour had a coefficient of 0.03326 and was significant at 1%. If the number of non-hired labour were to increase by one, the difference on the logs of expected counts will increase by 0.03326. There was therefore a positive and significant impact of non-hired labour on the intensity of adoption of cocoa research innovations. The finding agrees with the stated hypothesis and the finding of Boahene (1995) who observed that cooperative labour had a positive and significant impact on the percentage area of land used for hybrid cocoa.

Own labour

Own labour had a coefficient of 0.00644 and was significant at 1%. Thus, if own labour increases by one unit, the difference on logs of expected counts will increase by 0.00644. The result shows that there was a positive relationship between own labour and intensity of adoption of cocoa research innovations. The finding agrees with that of Hicks and Johnson (1974) who observed a positive relationship between own labour and adoption of technology. The finding in this study indicates that farmers who own their farms are prepared to sacrifice to adopt cultural practices which will enhance their output.

Membership of an association

Membership of an association had a coefficient of 0.02767 and was significant at 5%. Thus, if membership of an association increases by one unit, the difference on logs of expected counts will increase by 0.02767. The result shows that there was a positive relationship between membership of an association and intensity of adoption of cocoa research innovations. Thus, the stated hypothesis has been confirmed.

Frequency of extension advice

The coefficient for frequency of extension advice was 0.03415. There is therefore a positive relationship between frequency of extension advice and the intensity of adoption of cocoa research innovations. Thus, if frequency of extension advice increases by one unit, the difference in logs of expected counts will increase by 0.03415. The result confirms the stated hypothesis that intensity of adoption is positively related to frequency of extension advice, a position held by Baah (2011).

Conclusion

This chapter considered the determinants of intensity of adoption of cocoa research innovations. The results indicate that factors which positively and significantly determined the intensity of adoption of cocoa research innovations were age of the farmer, household size, farm size, primary education and JSS/Middle. Other variables which had positive relationship with adoption were access to credit, hired labour, non-hired labour, farmer's own labour, membership of an association and frequency of extension advice. With exception of age the farmer, all other variables had their expected signs. Age was postulated to have a negative sign but the results indicated a positive sign. Despite the change in sign for age of the farmer it was significant. It can therefore be stated that policies to increase intensity of adoption of cocoa research innovations should target these determinants: age of the farmer, household size, farm size, primary education, JSS/Middle education, access to credit, hired labour, non-hired labour, farmer's own labour, membership of an association and frequency of extension advice.

CHAPTER EIGHT

THE EFFECTS OF INTENSITY OF ADOPTION AND OTHER CHARACTERISTICS OF FARMERS ON COCOA OUTPUT

Introduction

In this chapter, we consider the impact of intensity of adoption of cocoa research innovations and other farmer characteristics on cocoa output. The chapter seeks to address hypotheses contained in the third model of the study. The chapter begins with a discussion of the theoretical and empirical models for the study. This is followed by explanation of the variables included in the model and their expected signs. The estimation method and discussion of the results then follow. The chapter ends with a summary of the main findings and assessment as to whether the study confirms the hypothesis or otherwise.

Theoretical model

The theoretical model which was based on the theory of production was explained in Chapter Four. The theory of production is the basis for explaining the behaviour of the cocoa farmer's production decision. The simplest and most common way to describe the technology of a firm is the production function. According to Varian (1992), in microeconomic theory, a production function is defined as the maximum possible output for a given level of input using the existing technology available to the firms involved.

Empirical model

Based on the theoretical model in equation 91 and the literature reviewed in chapter three, the model to be estimated to assess the impact of intensity of adoption of the recommended practices on output was as stated in equation. The prices contained in the theoretical model were omitted because they are not solely determined by the farmer.

$$\begin{aligned} \ln yield = {} & \beta_0 + \beta_1 Age + \beta_2 hhsize + \beta_3 \ln farmsize + \\ & \beta_4 edulev2 + \beta_5 edulev3 + \beta_6 edulev4 + \beta_7 edulev5 + \beta_8 \ln hirelab \\ & + \beta_9 \ln labour1 + \beta_{10} ownlab + \beta_{11} memasso + \beta_{12} freqadvice \\ & + \beta_{13} credit + \beta_{14} adoptintense + \varepsilon \end{aligned} \qquad (91)$$

The expected signs of the coefficients are:

$\beta_1 < 0$; $\beta_2 > 0$; $\beta_3 > 0$; $\beta_4 > 0$; $\beta_5 > 0$; $\beta_6, > 0$; $\beta_7 > 0$; $\beta_8 > 0$; $\beta_9 > 0$; $\beta_{10} > 0$; $\beta_{11} > 0$; $\beta_{12} > 0$; $\beta_{13} > 0$; $\beta_{14} > 0$

Where

lnyield is natural logarithm of output, *Age* is farmer's age ; *hhsize* is household size; *lnfarmsize* refers to the logarithm of size of the cocoa farm; *edulev2* refers to primary education; *edulev3* is junior secondary/middle school education; *edulev4* is secondary education; *edulev5* is tertiary education, *lnhirelab* is the logarithm of hired labour; *lnlabour1* is logarithm of non-hired labour such as spouse labour and reciprocal labour; *ownlab* refers to farmer's own labour; *memasso* is membership of a farmer based association; *freqadvice* is frequency of advice received from extension officers; *credit* is access to credit, *adoptintense* is intensity of adoption of cocoa research innovations; and ε the error term.

Variables in the model and their expected signs

The new variable introduced in this chapter is the logarithm of output (lnyield). All the other variables contained in chapters six and seven namely age of the farmer, household size, farm size, educational status, hired labour, non-hired labour, own labour, membership of an association and frequency of extension advice, remain unchanged.

Logarithm of output (*lnyield*)

The dependent and explanatory variables used in the study are shown in Table 22. The dependent variable is the log of yield (*lnyield*) which measures the output per acre of cocoa farm. Using the natural logarithm of yield limits the influence of outlier observations, and offers an intuitive interpretation of the estimated coefficients in terms of the percentage change in yield associated with a one-unit change in each variable. The explanatory variables and their expected signs are described below.

Age of the farmer

Age is defined using last birthday and rounded off to the nearest whole number. Age squared is the square of the farmer's age. According to Adesina and Forson (1995) the expected impact of age on technology adoption and for that matter output is an empirical question. There is no agreement in the adoption literature on the direction of the effect. In this study, however, it is postulated that there is a negative relationship between age and output of the farm.

Household size

Household is defined as all the people living together in a house. These may include the household head, his or her spouse, their children and other dependants. In the Ghanaian culture members of a household may include members of the extended family. In agreement with Croppenstedt, Demeke and Meschi (2003), it is expected that a larger household size will lead to availability of labour and so positively affect output.

Education

Education refers to formal schooling received by the farmer. Education was divided into five namely: no formal education, primary education, Junior Secondary School (JSS) or Middle school, secondary education/ technical/vocational/teacher training and tertiary (university, polytechnic, etc). The study hypothesises that there is a positive relationship between education and output on the farm in line with the position held by Olwande, Sikei and Mathenge (2009) and Alene, Poonyth and Hassan (2000).

Hired labour

Hired labour refers to labourers who are engaged to work on the farm for which payment is made daily, weekly or monthly depending on the agreement reached. The number of labourers engaged may depend on the size of the farm and the volume of activities to be performed. In agreement with

Edwin and Masters (2005), it is postulated that there is a positive relationship between hired labour and output on the farm.

Non-hired labour

Non-hired labour is made up of farm hands for which the farmer does not pay wages or salaries. They include reciprocal labour and labour provided by members of the household. It is expected that there will be a positive relationship between non-hired labour and output on the farm, a position held by Legese et al (2009).

Own labour

Own labour is the labour provided by the farmer himself. The effect of own labour on technology adoption depends on the health of the farmer. If the farmer is strong he may be able to perform most of the prescribed activities himself and thus, positively affect output. On the other hand, where the farmer is weak his contribution will not be significant. In agreement with Hicks and Johnson (1974), the study predicted a positive relationship between own labour and output.

Membership of an association

Membership of an association refers to farmers joining societies or clubs or associations where issues on cocoa are discussed. The associations may be producer association in which case issues concerning cocoa production dominate their activities or they may be marketing associations usually formed by the licensed cocoa buying companies to ensure the produce from the members are sold to them. It was expected that there would be a positive relationship between membership of association and output on the farm in agreement with Shiferaw et al (2010).

Frequency of extension advice

Frequency of advice from extension officers measured the number of times farmers received advice from extension officers in a year. It was expected that there would be a positive relationship between frequency of advice from extension officers and output on the farm in consonance with the position held by Aneani et al (2011), Alene et al (2000) and Legese et al (2009).

Intensity of adoption

Intensity of adoption measures the degree or extent of adoption of a technology. In this study, intensity is measured using a scale 0 to 100%. Farmers who have fully complied with all the recommendations made by CRIG scored 100%. In agreement with Islam (2002), El-Osta and Morehart (2000) and Edwin and Masters (2005), it is expected that there is a positive relationship between intensity of technology adoption and output on the farm.

Estimation method for the impact of adoption on output

The model in equation 91 was estimated with ordinary least squares (OLS) to capture the effects of intensity of adoption of cocoa research innovations and other famer characteristics on cocoa output. The method of OLS is used popularly not only because it is easy to use but also because it has some strong theoretical properties which are summarised in the well known Gauss-Markov theorem. The theorem states that given the assumption of the classical linear regression model, the OLS estimates have minimum variance in the class of linear estimators; that is, they are best, linear, unbiased estimates (BLUE). Also, the computational procedure of OLS is fairly simple compared with other econometric techniques and the data requirement are not excessive. The t statistic was used to test for the statistical significance of the coefficients of the independent variables. Heteroscedasticity was solved through the estimation of robust standard errors. R^2 was used to test the explanatory power of the model.

Measurement of variables in the model

The descriptive statistics of variables in the model are presented in Table 7. The frequency distributions for variables used in the previous chapters namely age of the farmer, household size, farm size, educational status, hired labour, non-hired labour, and own labour are not repeated in this chapter.

Cocoa output

Cocoa output is usually measured in bags. The bags are made up of jute. A bag of cocoa is usually 62.5 Kilograms and there are 16 bags in a tonne of cocoa whilst a tonne of cocoa weighs 1,000 Kilograms. Yield refers to the output of cocoa per acre. Table 22 shows the frequency distribution of output of respondents.

Age of the farmer

The average age of farmers was 50.12 years. This suggests that most of the farmers are of middle age. This finding is similar to the findings of Boahene (1995) who had the average age of farmers as 53 years; Hainmuelier, Hiscox and Tampe (2011) who had average age of farmers to be 50 years and the Ghana Living Standard Survey (2008) which had average age of farmers to be 45.3 years. The minimum value for age squared is 484 whilst the maximum value is 7,225. The mean and standard deviation of age squared are 2,514.77 and 1,335.97 respectively.

Household size

Household size measured the number of people living in a family and the average was 5 per household. This agrees with the findings of the GLSS (2008) and Hainmuelier et al (2011).

Farm size

The average farm size was 4.9 acres and agrees with the finding of Hainmuelier et al (2011). This shows that most of the cocoa farmers were small scale farmers. This is one of the characteristics of the cocoa industry which is dominated by small scale farmers.

Education status

Farmers with no formal education were 130. Majority of the farmers had middle school or junior secondary school education. The total number of farmers who had secondary and tertiary education was 52 which constituted about 9 per cent of the total respondents. Educational standard of most cocoa farmers can therefore be considered to be low. Hainmuelier et al (2011) also observed that most farmers had middle school or junior secondary school education. This is perhaps due the fact that graduates from the universities are not prepared to go into farming in general.

Hired labour

The number of labourers hired by farmers ranged between 0 and 10. This finding agreed with the finding of Hainmuelier et al (2011). About 28.83% of the farmers hired an average of three (3) labourers on their farms. Only one farmer indicated that he did not hire any labour on his farm because the farm was only two acres and besides he had adequate capacity to work on the farm.

Non-hired labour

About 28.67% of the respondents used 2 people they did not hire on their farms, which agrees with the finding of Hainmuelier et al (2011). About 87.83 per cent of the respondents used up to 4 people on their farms with the remaining 12.17 per cent engaging 5 to 9 people on their farms.

Own labour

About 397 of the respondents indicated that they use their own labour on their farms. Perhaps it is due to the fact that because the farm sizes are small the farmers are able to manage them without additional hands. Other survey such as those of Hainmuelier et al (2011) and MMYE (2008) also identified the farmer's own labour to be a major source of labour on the cocoa farm.

Intensity of adoption

The intensity of adoption measured the degree to which the farmers had adopted the CRIG recommended technologies. About 173 of the respondents did not adopt any of the technologies recommended by CRIG. 22.8% of the respondents had adoption rates of between 71 and 80 per cent. Those who had adoption rates of between 81 and 100 per cent constituted about 18.1 per cent. The rates are higher than Aneani et al (2012) who had adoption rates of between 0 and 44 per cent. It is however worth noting that the methodologies employed are different and that might have accounted for the differences in the adoption rates.

Results of estimation of the impact of intensity of adoption on output

The results of the OLS estimation of equation have been presented in Table 23. The dependent variable was log of yield per acre (*lnyield*). The R^2 of 0.7897 means that the explanatory variables are able to explain about 78.9 per cent of the changes in the dependent variable, output. The t statistics were used to test the significance of the individual variables. The intercept coefficient of 4.45464 is highly significant at 1 per cent which means that there were other factors which explain output but were not captured in the explanatory variables.

Table 23: OLS regression results for impact of technology adoption and other farmer characteristics on cocoa output

Lnyield	Coef.	Std. Err.	T	P>t	[95%	Interval]
Age	-0.0007	0.0008	-0.96	0.336	-0.0023	0.0008
HHsize	0.0249**	0.0092	2.70	0.007	0.0067	0.0431
lnfarmsize	1.0746***	0.0281	38.30	0.000	1.0195	1.1297
edulev2	0.0349	0.0246	1.42	0.157	-0.0134	0.0834
edulev3	0.4822*	0.0221	2.19	0.029	0.0048	0.0915
edulev4	0.0291	0.0341	0.85	0.393	-0.0378	0.0960
edulev5	-0.0419	0.1122	-0.37	0.709	-0.2624	0.1786
lnhiredlab	0.0505**	0.0193	2.61	0.009	0.0125	0.0885
lnNonhiredlab	-0.0223	0.0143	-1.57	0.118	-0.0504	0.0057
Ownlab	-0.0384	0.0193	-1.99	0.047	-0.0763	-0.0005
Memasso	0.0320*	0.0150	2.13	0.030	0.0020	0.0610
Frqadvice	0.0114**	0.0040	2.85	0.005	0.0035	0.0193
Credit	0.0597*	0.0232	2.58	0.010	0.0142	0.1053
Adoptintense	0.0986*	0.0416	2.37	0.018	0.0169	0.1804
Constant	4.4546***	0.2066	21.56	0.000	4.0485	4.8608

Source: Computed from Fieldwork, 2011

Notes: Reference point for education is no education.

*** = significant at 1%; ** = significant at 5%; * = significant at 10%

No. of observation = 425; F(14,410) = 142.22; R2 = 0.7897; Root MSE = 0.1398

Discussion of results

The variables which significantly affected the output are discussed in this section. They were intensity of adoption, household size, farm size, education, hired labour, membership of association, frequency of extension advice and access to credit.

Intensity of adoption

In line with expectation from the hypothesis and literature, intensity of adoption had a positive impact on output of cocoa. The coefficient of intensity of adoption is 0.09864 and was significant at 10 per cent. This showed that a unit increase in the intensity of adoption of cocoa research innovation would increase output by 0.098 per cent holding other variables constant. This confirms the finding of Wiredu et al (2011), Donkoh (2006) and Wu (2005) who identified a positive relationship between productivity and improved technology.

The farmer has to follow prescribed cultural practices prescribed by CRIG to achieve the increase in output. The cultural practices include maintenance of the farm by weeding at least twice in a year, pruning semi parasitic mistletoe plant from the cocoa trees and cutting down cocoa trees affected by swollen shoot virus disease and painting the stump surface with aboricide. To improve soil fertility, the farmer has to apply fertilizer in prescribed quantities. The farmer has to spray fungicides in right quantities to control black pod disease and spray insecticides to control insects such as black ants, stem borers, mealy bugs, termites and red ants. Ripe cocoa should be harvested; fermentation should be between six and seven days and should be turned twice on the third and fifth days. The cocoa should be dried daily in the sun on raised mats and should be properly dried before they are put in sacks for sale.

Household size

Results from the study indicated that the coefficient of household size was 0.02491 and was significant at 5 per cent. Thus, there was a positive relationship between household size and output of cocoa. This finding agrees with the hypothesis stated and the finding of Owu (1995). The possible explanation for this finding is that members of the household might have seen the need to devote much of their effort into cocoa production in order to earn a living.

Farm size

The coefficient of *lnfarmsize* was 1.07460 and was significant at 1 per cent. This shows that there was a positive relationship between farm size and output of cocoa. The finding confirms the stated hypothesis that there will be a positive relationship between farm size and output of cocoa. Also, the finding is consistent with those of Teal and Vigneri (2004), Vigneri (2008) and Aneani et al (2011) who found positive relationship between farm size and cocoa output. The results indicate that as more and more land is put into cocoa cultivation output will increase. It is however worth noting that land for cocoa cultivation is dwindling as the years go by and so it is important to adopt other technologies such as fertilizer application to increase the output without increasing the size of the land under cocoa cultivation.

Education

Education was divided into several levels such as primary education, middle school, secondary school and tertiary education. The results indicated that only middle school education was significant at 10 per cent with a coefficient of 0.4822. The results indicate that farmers with a minimum of middle school education are likely to adopt the recommended practices and for that matter have higher cocoa output than farmers with no education at all, other things being equal. The finding confirms the stated hypothesis that output of cocoa is positively related to farmer's education. The finding agrees with that of Teal and Vigneri (2004) who have a positive relationship between education and output of cocoa. The reason may be that farmers with a minimum of middle school education are able to read and understand basic farming information provided by extension officers and other media as compared to those without any formal education.

Hired labour

The coefficient of *lnhiredlabour* was 0.05051 and was significant at 5 per cent. This means there was a positive relationship between hired labour and cocoa output. This finding agrees with the stated hypothesis and the finding of Boahene (1999) who had a positive relationship between hired labour and output. The finding indicates that if the farmers have labour they are able to increase their output since most of the activities performed on the cocoa farms are labour intensive.

Membership of association

The coefficient for membership of association was 0.0320 and was significant at 10%. Membership of an association therefore has a positive effect on output and confirms the stated hypothesis. Membership of an association exposes farmers to new information and technical skills about cocoa production. This finding is consistent with the results of Kyei, Foli and Ankoh (2011) and Opoku et al (2009) who observed in their study of Cocoa Abrabopa Association (CAA), a private-sector initiative in Ghana's cocoa industry that there is evidence of large agronomic returns to participation in the programme.

Frequency of extension advice

The coefficient for frequency of extension advice was 0.01143 and significant at 5 per cent. There is therefore a positive relationship between output and frequency of extension service. The result confirms the stated hypothesis and indicates that farmers who frequently obtain extension service are likely to adopt improved production methods which will ultimately result in increase in output. This finding agrees with that of Baah and Anchirinah (2011) that extension activities have greatly improved adoption of CRIG recommended practices.

Access to credit

The coefficient for access to credit was 0.05977 and was significant at 10%. The results indicate that there was a positive relationship between access to credit and output of cocoa. The finding confirms the stated hypothesis and agrees with the findings of Opoku et al (2009). Farmers require inputs such as fertilizers, fungicides and hired labour on their farms. These inputs have to be paid for but the income of farmers is seasonal. There is therefore the need for credit to finance their operations until they harvest and sell their produce. Farmers with access to credit are therefore likely to get increased output, other things being equal.

Conclusion

Adoption of cocoa research innovations has potential to significantly increase cocoa output as envisaged by the Cocoa Research Institute of Ghana. The results of this study indicate that intensity of adoption of cocoa research innovations, household size, farm size, education, hired labour, membership of association, frequency of extension advice and access to credit significantly and positively affected the output per hectare. Thus, the results confirm the hypothesis that there is a positive relationship between intensity of adoption of cocoa research innovations and output. Policies to improve output should therefore target the adoption of improved technologies.

CHAPTER NINE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

The previous three chapters dealt with discussion of the results of empirical findings on the determinants of adoption, intensity of adoption and the impact of adoption on output. This last chapter presents summary of the main findings of the study, conclusions which can be drawn on the findings and recommendations which will enhance adoption of cocoa research innovations and for that matter increase the output of cocoa. Also discussed in the chapter are limitations to the study and suggestions for future research.

Summary

The Ghanaian economy depends largely on agriculture with the cocoa sector being the most dominant. Cocoa contributed about 4 per cent out of the total agricultural contribution of 29.8 percent to the GDP in 2010. The contribution of industry and services for the same year, 2010 were 19.1% and 51.1% respectively (ISSER, 2012). The industry employs between 720,000 and 800,000 families at the farmer level (Anim Kwapong et al, 2004). The cocoa sector, through COCOBOD contributed funds to the Road Fund for the construction of roads (Kolavalli, Vigneri, Maamah & Poku 2012).

The cocoa sector contributes significantly to the foreign exchange earning of the country. In 2011 revenue from cocoa, minerals, timber and non-traditional exports as a percentage of total export revenue were 22.5, 39.6, 1.3 and 2.3 respectively (ISSER, 2012). In the 2009/10 academic year the sector, through COCOBOD, provided scholarships to 2,620 brilliant but needy children of cocoa farmers (COCOBOD, 2011)

To be able to significantly improve cocoa output, there is the need for modification of the production techniques through the adoption of modern technology conducive to the Ghanaian environment. There have been a number of policy interventions to boost cocoa production. These have been in the areas of disease and pests control, farm rehabilitation, producer price management, produce payment processes, soil fertility management, planting materials and research and extension.

Based on research results of CRIG), the government introduced two important programmes namely CODAPEC and Cocoa Hi-Tech. CODAPEC is the national pest and disease control programme initiated in 2001 by the government to help address disease and pests which are major causes of decline in cocoa production. The cocoa Hi-Tech is a holistic approach to sustainable cocoa production in which all the recommended technologies by CRIG are packaged into one programme. The Hi-Tech programme began in the 2003/04 cocoa season.

The main components of the Hi-Tech programme are: cultural maintenance of farm; application of fertilizer; spraying of fungicides; spraying of insecticides; and harvesting, fermentation and drying technologies. According to Bosompem et al (2008) the cultural maintenance component of the programme generally prepares the cocoa trees and cocoa farms so that cocoa trees would make maximum use of the fertilizer when applied. Cultural maintenance includes weeding, of the cocoa farm, removal of basal chupons, overhead canopies and mistletoe.

Application of fertilizer follows immediately after cultural maintenance. In using the conventional type of fertilizer the rate of application is expected to be 300 – 400 grams per tree per year and it is applied 70 – 100 centimetres around each tree trunk. Foliar/liquid fertilizers are sprayed on the leaves at monthly intervals. The recommended type is Sidalco liquid fertilizer. Organic fertilizer include poultry manure, cocoa pod husk ash, compost etc but are not common. Fungicide application involved the spraying of Nordox and Rindomil when the trees start bearing flowers and smaller pods in order to control black pod disease. The cocoa trees and pods are sprayed to treat capsid insects using insecticides such as Confidor. The fertilizers are supplied by traditional suppliers and have been tested and approved to be used by CRIG. The government subsidises the price of fertilizers to make them affordable to the cocoa farmers.

To achieve maximum bean quality, harvesting of ripe cocoa pods must be done at the right time; there should be fermentation for about 6 – 7 days after opening the pods, and turning of beans in heap at 48 and 96 hours intervals. At the end of the fermentation, drying begins. It is done the same day fermentation ends. Drying is the reduction of moisture in fermented beans from about 55% to about 7%. There are two types of drying namely sun drying and mechanical drying. Mechanical drying is not recommended because it is expensive and there is danger of smoke contamination and high acid retention in the beans. The beans are well dried when they produce a "cracking" sound after pressing them lightly in the fist. Well fermented and well dried beans are brown in colour. After drying, the cocoa beans are cleaned of any extraneous matter and packed into clean, strong jute bags. The dried beans are stored in well ventilated storage room with relatively low humidity to avoid rehumidification of the beans. The bags of cocoa must be packed on wood pallets to avoid rodents and insect pests.

Results from CRIG experimental farms indicated that yield per hectare increased from 360 Kilograms to 1,300 Kilogram (Appiah et al, 1997). Several studies have shown that farmers' yield increased if they adopt improved technologies. For example Edwin and Masters (2003) indicated that farmers who planted hybrid varieties had 42% higher yields whilst fertilizer use had 19% higher yield. According to Bosompem et al (2008), farmers who used Hi-Tech had mean increase in their output by 72% (i.e. an increase from 2.85 bags per acre to 4.9 bags per acre). Similarly, Opoku et al (2009) observed that farmers who used Hi-Tech increased their yield per hectare by 638.5 Kilograms instead of 435 Kilograms estimated. Also, Wiredu et al (2011) found that land productivity increased by 1.84 units and 3.71 units if farmers decided to adopt and use hybrid varieties respectively.

Despite these findings, some cocoa farmers are not taking advantage of this technology. Objectives of the study were therefore to identify factors determining adoption and intensity of adoption of cocoa research innovations in Ghana. It was also to find out the effects of intensity of adoption of cocoa research innovations on output and to prescribe policy recommendations for interventions needed to spur the rate of technology adoption.

The study used primary data gathered with the aid of questionnaire administered by cocoa extension officers to 600 farmers selected from five cocoa growing regions namely, Ashanti, Brong Ahafo, Central, Eastern and Western regions. Multi-stage sampling technique was used to select farmers for the study.

Intensity of adoption was measured as the degree to which the various cultural practices had been adopted. The intensity of adoption computed for the various cultural practices were 53.1%, 48.9%, 46.1%, 46.2% and 56.4% for weeding, spraying, fertilizer application, fermentation and drying of cocoa respectively.

There were three empirical models for the study. The first and second models were estimated with the double hurdle model. The first hurdle which was a logit dealt with the determinants of adoption whilst the second hurdle which was a Poisson regression dealt with intensity of adoption of cocoa research innovations.

Results of the determinants of adoption indicated that age was statistically significant and the average age of farmers was 50.12 years. Age was negatively related to adoption implying as farmers grow, they tend to be more conservative and risk averse in the use of new technology. Similarly, non-hired labour had a negative relationship with adoption. Also, education was statistically significant and majority of the farmers (50.3%) had formal education up to the middle school or junior secondary school level. Other variables which positively and significantly determined the level of adoption were household size, farm size, hired labour, own labour, membership of an association and frequency of extension advice.

In the case of determinants of intensity of adoption of cocoa research innovations, variables which were found to be significant were age of the farmer, household size, farm size, education (primary and middle school), access to credit, hired labour, non-hired labour, own labour, membership of association and frequency of extension advice. However, age of the farmer had a positive relationship with intensity of adoption contrary to the hypothesis postulated that it will have a negative relationship.

The method of ordinary least squares (OLS) was employed to estimate the impact of intensity of adoption of cocoa research innovations and other farmer characteristics on output of cocoa. The dependent variable was log of yield per acre (lnyield). Even though the emphasis was on the impact of intensity of adoption on output, other variables were included in the model. The results of this study showed that farmers who adopted improved technologies had an average yield of 771.67 Kilograms per hectare as compared to 389 Kilograms per hectare obtained by Hainmuelier et al (2011) as the highest yield per acre by those who did not adopt. The results confirm those obtained by other studies that improved technologies lead to increase in output. For example Naminse et al (2012) showed that cocoa yield increased by 49.41 per cent if farmers adopted improved technology. Also, Oduro and Omane-Adjepong (2012) observed that mass spraying led to an increase of 183,398.3 mt per hectare while Hi-Tech lead to an increase by 266,515 mt per hectare. Finally, Ruf and Bini (2012) found that cocoa yield increased by 127 per cent as a result of fertilizer use.

The results further indicated that determinants of output included intensity of adoption of cocoa research innovations, household size, farm size, education, hired labour, membership of association, frequency of extension advice and access to credit significantly affected the cocoa output per acre.

Conclusions

Innovations considered in this study were: adoption of hybrid varieties; cultural maintenance of farm; proper application of fertilizer; control of insect pests and diseases through spraying of fungicides and insecticides; proper harvesting of cocoa; proper fermentation of cocoa beans; and proper method for drying cocoa beans. Studies have shown that adoption of cocoa research innovations has potential to significantly increase cocoa output from 389 kg per hectare reported by Hainmuelier et al (2011) to 1,300 kg per hectare as envisaged by the Cocoa Research Institute of Ghana. Results of this study also indicated that farmers who adopted improved technologies had output of 771.67 kg per hectare.

Results of this study indicated that adoption, intensity of adoption and output were influenced by economic, demographic as well as sociological factors explained below. Age of the farmer was negatively related to adoption but positively related to intensity of adoption. The variable was not significant in determining output. Involving the youth in cocoa farming will, other things being equal, increase adoption.

Household size positively and significantly affected adoption, intensity of adoption and output of cocoa. Thus, involvement of members of households in the production of cocoa will not only increase adoption but increase output. Farm size impacted positively on adoption, intensity of adoption and output of cocoa. Increase in size of farm sizes will, other things being equal, lead to increase in output. However, since virgin lands are being depleted it is very important to intensify the use of existing farms through adoption of improved farming methods.

Education, especially primary and middle/junior secondary school education positively affected intensity of adoption Tertiary education was however not significant in determining adoption, intensity of adoption and output. Credit access was significant and positively affected adoption, intensity of adoption and output. Making credit available to farmers will other things being equal lead to increase in adoption and for that matter output. Labour availability was significant in determining adoption, intensity of adoption and output. Hired labour had positive influence in all the three models. Non-hired labour had a negative relationship with adoption and a positive relationship with intensity of adoption but was not significant in determining output.

Membership of an association had positive coefficient in all the three models implying they determined adoption, intensity of adoption and output. Participation of farms in groups where cocoa matters are discussed, will other things equal lead to adoption, intensity of adoption and increase in output.

Frequency of extension advice had positive relationship with adoption, intensity of adoption and output. Encouraging extension officers to visit the farms and provide guidance to the farmers will other things being equal lead to adoption, intensity of adoption and increase in output.

Recommendations

In the light of the above findings, the following are recommended:

1. The government and District Assemblies should tackle the issue of land ownership to solve the problem of lack of access to land which limit farm size. The land reform project currently underway to reform land administration should be expedited to give specific attention to cocoa farm lands. Also, since access to new farm lands is a problem, existing farmers should be encouraged to adopt the innovation introduced by COCOBOD to increase land productivity.
2. COCOBOD should make production of cocoa attractive to the youth by improving upon conditions in the cocoa growing communities through increase in scholarship to children of cocoa farmers and improvement in the housing scheme for cocoa farmers. Furthermore, COCOBOD should increase the fund allocation to the Ministry of Roads and Highways for improvement of roads in the cocoa growing communities. These interventions by COCOBOD, among others, will go a long way to motivate the youth to remain in the cocoa growing areas to take over for their ageing parents. It is expected that once the youth become interested in cocoa production and grasp the technology, the problem of ageing cocoa farmers will be minimized if not eliminated completely.
3. COCOBOD and LBCs should educate cocoa farmers through non-formal education in the cocoa farms to enable them appreciate the importance of adopting the recommended cocoa technologies in order to increase output. COCOBOD, through CRIG, has developed a curriculum for training of extension officers. This curriculum should be used for Farmer Field School (FFS) which is a learning-centred

intervention which uses discovery learning and adult education principles to improve farmer knowledge and strengthen decision-making. By participating in FFS and other training activities, farmers have the opportunity to increase their skills and knowledge about good agricultural practices as well as responsible and safe labour practices. According to Soniia and Asamoah (2011), evidence from Ghana suggest that FFS on cocoa led to improvements in key aspects of human and social capital development among participating farmers.

4. Financial institutions, LBCs, microfinance institutions and COCOBOD should educate cocoa farmers on the requirements for accessing credit. They should also teach the farmers the need to repay facilities extended to them.

5. COCOBOD and LBCs should encourage cocoa farmers to join producer associations such as the Cocoa Abrabopa Association where techniques of cocoa farming are discussed, marketing associations and credit unions. Farmers need to be sensitized about the benefits of belonging to an association which include reduced price which emanate from the ability to negotiate due to bulk purchase, access to credit because group members serve as collateral, forum for dissemination of technological innovation and best farming practices.

6. COCOBOD should intensify the extension services provided to cocoa farmers. The operation of dedicated extension service for cocoa farmers by the Cocoa Services Division of COCOBOD was ceded to the Ministry of Food and Agriculture (MOFA). The government made the extension service part of a unified agricultural extension service

under MOFA. Many cocoa farmers complained that extension officers did not visit them and did not get introduced to innovations in cocoa production. In 2010 the government brought back cocoa extension to COCOBOD and it is now implemented with a public-private partnership also by the CSSVD Control Unit. The seed Production Unit of COCOBOD supplies seeds and seedlings to producers.

Contribution of the thesis to knowledge

The thesis has contributed to knowledge in two ways. First, the data gathered from the survey will serve as a source of reference for further studies by other researchers. Thus, time and financial resources which will be needed for gathering data for a similar study will be saved.

Second, the double hurdle model has not been used to analyse adoption of cocoa research innovations in Ghana and so it is a novelty. The study has therefore contributed to the methodology for analysing technology adoption in the Ghanaian cocoa industry.

Limitations of the study

There was the possibility that some farmers interviewed were caretakers and that the real farm owners who took decisions on technology adoption were absentee farmers residing in the cities. Thus information provided may not be the complete true picture of what pertains on the farm.

Also, the impact of the adoption of cocoa research innovation could have been properly measured if two groups of farmers were selected and one allowed using the technology prescribed by CRIG and the other group not adopting any improved method of production. This effect can be well evaluated over a minimum period of two to three years however time for the research for this programme did not permit such an evaluation to be done.

Suggestions for future research

In the light of the limitations of the study, the following suggestions are made for future research. There should be a study on the determinants of intensity adoption of fertilizer use, fungicide use or insecticide use by cocoa farmers through the use of controlled group method. That is, one group which has accessed the technology against another group which did not apply the technology. Another suggestion is the use of panel study to analyse the impact of technology adoption on output since it has advantage of introducing time dimension and thus help to properly evaluate the impact of technology adoption on output.

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APPENDICES

Appendix A

Contribution of cocoa to the GDP of Ghana

Year	GDP Value (in GHCMillion)	Contribution of cocoa to GDP (%)
2001	3,801.4	3.3
2002	4,776.4	3.3
2003	6,226.7	3.5
2004	7,980.4	4.2
2005	9,701.8	4.5
2006	11,493.0	2.0
2007	13,976.7	6.5
2008	17,211.7	5.0
2009	36,867.0	6.2
2010	44,799.0	4.0

Source: ISSER ,State of the Ghanaian Economy , 2005, 2006, 2008, 2010

Appendix B

Total export and local duties on cocoa

Crop Year	Quantity in MT	F.O.B Price US$	Value in US $ million	Total Duty GHC
2000	348.0	1,094.4	380.9	17,881,400
2001	310.5	1,020.8	316.9	29,961,200
2002	311.4	1,260.5	392.5	33,526,600
2003	354.8	1,949.5	691.6	78,390.300
2004	620.4	1,586.9	984.4	99,720,000
2005	536.9	1,524.5	818.5	64,119,000
2006	657.2	1,584.1	1,041.1	61,600,000
2007	545.9	1,787.2	975.7	92,055,200
2008	564.0	2,172.4	1,225.1	46,252,800
2009	508.2	2,798.8	1,422.4	85,473,828
2010	547.4	3,032.4	1,660.0	153,933,253

Sources: 1. Ghana Cocoa Board Annual Reports and Accounts, 2000 to 2010

2. State of Ghanaian Economy 2000 to 2010

Appendix C

Foreign exchange earned from cocoa export

Year	Revenue US$ Million	Total Export US$ Million	Revenue as a percentage of Total Export Revenue
2000	437	1,941	22.5
2001	381	1,867	20.4
2002	463	2,064	22.4
2003	818	2,297	34.9
2004	1,071	2,733	39.2
2005	908	2,802	32.4
2006	1,187	3,735	31.8
2007	1,103	4,195	26.3
2008	1,502	5,275	28.5
2009	1,866	5,991	31.1
2010	2,285	8,190	27.9

Source: ISSER, State of the Ghanaian Economy, 2000, 2003, 2005, 2007, 2008, 2009 & 2010

Appendix D

Ghana COCOBOD scholarship scheme beneficiaries

Crop Year	No. of Beneficiaries	Payment Per Term GHC	Total Payment GHC
2001/02	3,000	39.20	352,800
2002/03	3,000	39.20	352,800
2003/04	3,000	51.33	461,970
2004/05	2,500	51.33	384,975
2005/06	2,500	67.68	507,600
2006/07	2,500	67.68	507,600
2007/08	2,500	74.67	560,025
2008/09	2,600	74.67	582,426
2009/10	2,620	114.80	902,328

Source: Ghana Cocoa Board Research Department

Appendix E

Funds paid by COCOBOD into road fund

Crop Year	Amount Paid in Ghana Cedis
2007/08	11,500,000
2008/09	40,000,000
2009/10	25,000,000
2010/11	71,000,000

Source: Ghana Cocoa Board Research Department

Appendix F: Trends of Cocoa Output in Ghana According to Regions – 1969/70 to 2010/11

Year	Ashanti	B. Ahafo	Central	Eastern	Volta	Western
1969/70	125,406	115,393	55,236	69,431	20,878	31,113
1970/71	130,544	112,037	59,713	73,865	15,340	36,395
1971/72	145,557	119,156	57,968	86,000	10,289	50,894
1972/73	125,648	112,754	43,497	74,627	22,188	43,129
1973/74	107,028	78,502	47,886	65,622	14,489	41,344
1974/75	109,802	81,526	50,766	73,393	14,009	31,787
1975/76	124,315	88,415	49,726	68,588	13,622	55,655
1976/77	104,215	78,326	38,547	53,452	98,228	40,343
1977/78	89,619	69,541	21,553	41,290	7,368	41,968
1978/79	86,913	50,408	25,702	50,200	5,980	45,873
1979/80	100,362	74,893	19,032	45,051	4,776	52,305
1980/81	91,537	47,598	25,563	46,632	1,496	45,148
1981/82	70,790	49,747	22,069	36,890	1,683	43,703
1982/83	55,310	35,173	17,604	31,254	3,776	35,509
1983/84	47,095	29,657	13,782	25,523	2,656	40,243
1984/85	44,928	28,756	19,070	28,540	1,028	52,487
1985/86	54,468	36,476	27,636	34,614	1,117	64,733
1986/87	56,870	32,644	26,912	33,399	1,903	76,037
1987/88	49,766	28,796	19,116	29,951	1,806	58,742
1988/89	76,268	48,647	28,423	39,193	1,676	105,894
1989/90	72,124	45,125	31,208	33,296	1,785	111,513

1990/91	60,958	42,016	26,517	32,261	2,645	128,955
1991/92	52,467	33,734	19,356	26,196	1,595	109,469
1992/93	65,355	37,016	29,587	34,619	2,272	143,274
1993/94	47,172	30,927	21,936	25,372	923	128,323
1994/95	64,025	37,014	20,518	33,667	1,067	153,161
1995/96	81,983	39,051	36,413	38,935	906	206,585
1996/97	64,534	34,195	22,415	34,305	1,678	165,361
1997/98	78,913	39,900	29,470	43,156	976	216,967
1998/99	74,448	40,244	29,676	40,535	2,062	210,710
1999/00	82,068	39,310	31,360	41,526	2,352	240,331
2000/01	72,994	33,109	32,136	46,225	1,680	203,627
2001/02	57,011	31,432	30,039	39,343	1,079	181,658
2002/03	82,445	45,309	39,989	51,604	913	276,586
2003/04	121,233	69,688	56,631	67,804	1,909	419,710
2004/05	90,535	55,025	48,868	59,308	1,336	344,246
2005/06	132,852	72,765	55,497	55,870	1,072	422,399
2006/07	95,427	65,629	43,887	51,002	761	357,827
2007/08	125,270	66,921	62,378	55,916	838	369,458
2008/09	110,642	61,560	60,986	63,406	951	413,393
2009/10	97,307	60,495	56,513	59,804	595	357,323
2010/11	169,943	102,195	78,198	79,699	3,286	591,232

Source: Ghana Cocoa Board, Research and Monitoring Department

Appendix G

Cocoa district in Ghana as at December 2011

Ashanti Region	Brong Ahafo Region	Central Region
Agona	Asumura	Asikuma
Ampenim	Dormaa Ahenkro	Assin Breku
Antoakrom	Goaso/Mim	Cape Coast
Bekwai	Hwidiem	Assin Foso
Effiduase	Kasapin	Nyinase
Juaso	Kukuom	Twifo Praso
Konongo	Nkrankwanta	Agona Swedru
Tepa	Sunyani	
Mankranso	Sankore	
New Edubiase		
Nkawie		
Nsokote		
Nyinahin		
Obuasi		
Offinso		

Appendix G Cont'd

Eastern Region	Western North	Western South
Achiase	Adabokrom	Agona Amenfi
Asamankese	Akontombra	Asankragwa
Kade	Sefwi	Bogoso
	Anhwiaso	
Kibi/Anyinam	Asawinso	Diaso
Koforidua/Tafo	Asempaneye	Dunkwa
Nkawkaw	Bonsu Nkwanta	Enchi
Akim Oda	Debiso	Dadieso
Akim Akoase	Essam	Manso Amenfi
Akim Ofoase	Fosukrom	Samreboi
Suhum	Juabeso	Tarkwa
	Sefwi Wiawso	Takoradi
	Sefwi Bekwai	Wassa Akropong
	Sefwi Kaase	

Source: Ghana Cocoa Board, Research and Monitoring Department

Appendix H

INTERVIEW SCHEDULE USED FOR THE STUDY

UNIVERSITY OF CAPE COAST

TITLE: COCOA RESEARCH INNOVATIONS AND OUTPUT IN GHANA

INTRODUCTION

This interview schedule is designed to solicit information on the above topic. Your responses will be for academic purposes only and will be treated highly confidential. Your candid opinion will therefore be very much appreciated.

GENERAL INFORMATION

Serial Number ....

Name of Respondent..

Name of Interviewer..

Date of Interview..

Region..

District..

Location (Town or Village)..

SECTION I: FARMER CHARACTERISTICS

1. Sex of respondent

    i. Male

    ii. Female

2. Age of respondent (using last birthday)

3. Marital Status of respondent

    i. Never married, not in union

ii. Loose union

iii. Married

iv. Separated

v. Divorced

vi. Widowed/widower

vii. Others

(specify)..

4. How many children do you have?

5. How many dependants (apart from your own biological children) live with you?

6. What is your highest level of formal education?

i. No education

ii. Primary education

iii. JSS/Middle School

iv. Secondary education/Technical/Vocational education/Teacher training

v. Tertiary education (university, polytechnic, etc)

SECTION II. FARM CHARACTERISTICS

7. What is the nature of your Farm ownership?

i. Indigenous Owner

ii. Migrant owner

iii. Migrant caretaker

iv. Indigenous caretaker

v. Tenant

vi. Other (specify) ....

8. What is the total size of your farm in acres? [ ]

9. How many acres are under cocoa cultivation? [ ]

10. How long have you been a cocoa farmer? [ ]

11. Do you hire labourers on your farm?

i. Yes

ii. No

12. If yes, how many labourers do you hire? [ ]

SECTION III. SOCIAL PARTICIPATION

13. Which of the following positions do you hold in this village?

i. A board member of the village political organization

ii. Chief farmer

iii. A member of the village development committee

iv. Chief/queen of the village

v. Member of royal family

vi. Head of clan

vii. Local priest

viii. Other (Specify) ....

14. Do you belong to any farmer organisation or association?

i. Yes

ii. No

15. If yes, what is the name of the organization? ....

16. How often do you attend meetings?

i. Once a week

ii. Once every two weeks

iii. Once a month

iv. Once every year

v. Others (Specify) ....

SECTION IV: KNOWLEDGE OF COCOA RESEARCH INNOVATIONS

17. Do you get advice from extension officers?

i. Yes

ii. No

18. How often do extension officers visit you?

i. Once per week

ii. Once per fortnight

iii. Once per month

iv. Once every six months

v. Once per year

vi. Other (specify) ....

19. Have you received training in cocoa production in the last three years?

i. Yes

ii. No

20. If yes, what was the means of information?

i. Demonstration

ii. Field day/visit

iii. Training

iv. Written materials (leaflets, manuals, etc)

v. Others (specify) ....

21. What type of cocoa do you grow on your farm?

i. Amelonado (Tetteh Quarshie)

ii. Amazon

iii. Hybrid (Akokora bedi)

22. What is the gestation period of the cocoa on your farm?

i. Less than three years

ii. Three years

iii. Four years

iv. Five years

v. More than five years

23. How many harvest seasons do you have in a year?

i. Once

ii. Twice

iii. Others (specify) ....

SECTION V: TECHNOLOGY ADOPTION

24. How often do you have to weed your farm in a year?

i. Once a year

ii. Twice a year

iii. Thrice a year

iv.. Four times a year

v. Other (specify) ....

25. Do you apply fertilizer on your farm?

i. Yes

ii. No

26. If yes, what type of fertilizer do you apply?

i. Granular fertilizers (Asaase Wura and Cocofeed)

ii. Liquid fertilizers (Sidalco Balanced and Sidalco Potassium Rich)

iii. Other (specify) ....

27. How do you get supply of fertilizer?

i. Cocoa Input Company Limited

ii. Ministry of Food and Agriculture

iii. Open Market

iv. Other (specify) ....

28. If you use granular fertilizers, what quantity of fertilizer do you apply per acre?

i. One bag per acre

ii. Two bags per acre

iii. Three bags per acre

iv. Four bags per acre.

v. Others (specify) ....

29. If you use liquid fertilizers (foliar fertilizers), what quantity do you apply per acre?

i. One litre per acre

ii. Two litres per acre

iii. Three litres per acre

iv. Four litres per acre

vi. Five litres per acre

vii. Other (specify) ....

30. Who makes the decision about the rate of fertilizer application?

i. Mass sprayers

ii. Farm owner

iii. Extension officer

iv. Other (specify) ....

31. How did you apply the fertilizer?

i. Broadcasting

ii. Ring method

iii. Placement method

iv. Spraying method

v. Other (specify) ....

32. When did you apply the fertilizer?

i. Rainy season

ii. Dry season

33. How do you rate your general level of fertilizer efficiency?

i. Very low

ii. Low

iii. Moderate

iv. High

v. Very High

34. Do you experience mistletoe on your farm?

i. Yes

ii. No

35. If yes, how do you handle them?

i. Prune the semi-parasitic mistletoe plant from the cocoa tree

ii. Cut down the cocoa tree

iii. Others

(specify)..

36. What tool did you use?

i. Cutlass

ii. standard pruner

iii. Other (specify) ....

37. Do you experience cocoa swollen shoot virus disease?

i. Yes

ii. No

38. If yes, how do you deal with the cocoa swollen shoot virus disease?

i. Cut down the cocoa tree and paint the stump surface with aboricide.

ii. Leave the tree to die

iii. Other

(specify)..

39. Which of the following insects do you experience on your farm?

i. Capsid insects or Mirids

ii. Black ants

iii. Stem borers

iv. Mealy bugs

v. Termites

vi. Red ants

vii. Other (specify) ....

40. Do you use insecticides on your farm?

i. Yes

ii. No

41. If yes, what type of insecticides do you use?

i. Confidor 200 SL (Imidacloprid)

ii. Akate Master (Bifenthrin)

iii. Actara (Thiamethoxam)

iv. Other (specify) ....

42. What quantity of insecticides do you use per acre?

i. 1 tank full of mixture per acre

ii. 2 tanks full of mixture per acre (60 mls per acre)

iii. Other

(specify)..

43. Where do you get your supply of insecticides?

i. Licensed Cocoa Buying Company

ii. Cocoa Input Company

iii. Ministry of Food and Agriculture

iv. Open Market

v. Other

(specify)..

.....

44. How many times do the mass sprayers use insecticides on your farm in a year?

i. Once

ii. Twice

iii. Thrice

iv. Other (specify) ....

45. How do the mass sprayers apply the insecticides?

i. Sprinkle it

ii. Use knapsack sprayer

iii. Use motorized mist blower

iv. Other (specify) ....

46. In the absence of mass sprayers do you spray your farm?

i. Yes

ii. No

47. If No, why don't you spray it?

i. No knowledge in the use of insecticides

ii. Insecticides are expensive

iii. Insecticides are not available

iv. Other (specify) ....

48. Do you experience black pod disease (Twi - Anonom) on your farm?

i. Yes

ii. No

49. If yes, how do you treat it?

i. Remove infested pod

ii. Reduce humidity

iii. Increase aeration

iv. Spraying with approved chemical.

v. Other (specify) ....

50. If spraying with chemical, which type do you use?

i. Ridomil Gold

ii. Funguran - OH

iii. Metalm 72 WP

iv. Fungi Kill 50 WP

v. Kocide 2000

vi. Nordox 75 WG

vii. Champion

viii. Other

(Specify)..

51. How many times do you spray fungicides annually?

i. Once

ii. Twice

iii. Thrice

iv. Other (specify) ....

52. When do you spray the fungicides?

i. When tree start bearing flowers and smaller pods

ii. When fruits are matured

iii. Others (specify)..

53. Do you use any protective method when spraying?

i. Yes

ii. No.

54. If yes, how do you protect yourself?

i. Put on gloves

ii. Cover nose

iii. Put on wellington boots.

iv. Other (specify) ....

SECTION VI. MEASUREMENT OF INTENSITY OF TECHNOLOGY ADOPTION

55. Please indicate the degree (intensity) to which you have adopted the modern

method of cocoa production (high tech)

Technology	Very Low (1)	Low (2)	Moderate (3)	High (4)	Very High (5)
Pre-planting					
Land Clearing					
Felling and Chopping					
Burning					
Stumping					
Pegs Cutting					
Lining and Pegging					
Planting					
Holing/Planting of suckers					
Preparation of seedlings					
Carrying of seedlings					

Holing for seedlings					
Planting of seedlings					
Sowing at stake					
Farm Maintenance					
Weeding (farm maintenance)					
Spraying of insecticides					
Applying fertilizer					
Applying fungicide/other chemicals					
Carrying water for spraying					
Sanitation and pruning					
Mistletoe control					
Harvesting					
Plucking of pods					
Gathering and heaping of pods					
Pod breaking and fermentation					
Scooping of cocoa beans					

Post Harvest					
Carting of fermented beans					
Drying of beans					
Carting dry beans for sale					

SECTION VII: OUTPUT OF COCOA

56. What is the yield in bags per acre on your farm? ....

57. How many bags of cocoa did you harvest last season? ....

58. How often did you harvest the pods when they began to ripe?

   i. Once every three weeks
   ii. Once every month
   iii. Once every two months
   iv. Others (specify) ....

59. How long did you do the fermentation?

   i. Less than three (3) days
   ii. 3 to 5 days
   iii. 6 to 7 days
   iv. 8 to 9 days
   v. Others (specify)..

60. How many times did you turn the beans during the fermenting period?

   i. Once

ii. Twice, on the third and fifth days

iii. Other (specify) ....

61. How did you dry the cocoa?

i. Daily in the sun on raised mat

ii. Daily in the sun on the floor

iii. Other (specify) ....

62. How did you store the cocoa?

i. In boxes

ii. In baskets

iii. In jute sacks raised from the ground

iv. Other (specify) ....

63. Where did you get supply of sacks?

i. Cocoa Input Company Limited

ii. Licensed Cocoa Buying Company

iii. Open Market

iv. Others (specify) ....

643. How did you transport the cocoa to the selling centre?

i. Carried them on the head

ii. Put them in a vehicle

iii. Other (Specify) ....

65. Which licensed cocoa buying company bought the cocoa?......................

66. How were you paid?

i. Cash

ii. Akuafo cheque?

iii. Other (Specify) ....

SECTION VIII. CREDIT ACCESS

67. How did you get money to finance your operations?

i. Use of income from previous season

ii. Personal savings

iii. Loan from money lender

iv. Loan from financial institution

v. Credit from supplier

vi. Other (specify) ....

68. Did you apply for a loan from a financial institution?

i. Yes

ii. No

69. If No, why didn't you apply for a loan?

i. Loan not available

ii. Interest rate is high

iii. Bank debt is too risky

iv. Does not meet bank's requirement

v. Don't know

vi. Other (specify) ....

70. If yes, were you granted?

i. Yes

ii. No

Appendix I: Spearman's correlation matrix for determinants of adoption

	adoptinten	Memas	freqadv	Hhsize	farmsiz	edlev2	edlev3	edlev4	credit	hlab	lab1	o'lab
adoptinten	1.0000											
Memas	-0.0639	1.0000										
freqadv	-0.1456	0.2659	1.0000									
hhsize	-0.0458	0.3641	0.3089	1.000								
farmsiz	0.1865	0.2845	0.0459	0.051	1.0000							
edlev2	0.0326	0.061	-0.0885	-0.001	-0.1768	1.0000						
edlev3	-0.0727	-0.2331	-0.0596	-0.094	0.1187	-0.160	1.0000					
edlev4	0.1645	-0.0916	0.0691	-0.103	-0.0037	-0.140	-0.256	1.0000				
credit	0.2618	-0.1356	-0.0631	-0.177	0.1973	0.1142	-0.006	-0.016	1.000			
hlab	0.1201	0.1935	0.0478	-0.023	0.2826	0.0032	-0.005	0.0645	0.257	1.000		
lab1	-0.0366	0.187	0.0249	-0.054	0.2862	-0.017	0.0125	0.0556	0.123	0.121	1.0000	
o'lab	-0.2655	0.0187	-0.0725	-0.11	-0.1135	0.2986	0.003	-0.198	-0.053	0.098	0.2888	1.0000