UNIVERSITY FOR DEVELOPMENT STUDIES, TAMALE

IMPROVED TOMATO SEED VARIETY ADOPTION, EFFICIENCY AND WELFARE OF FARMERS IN SELECTED AGRO-ECOLOGICAL ZONES OF GHANA

ADINAN BAHAHUDEEN SHAFIWU

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IMPROVED TOMATO *(LYCOPERSICON ESCULENTUM)* SEED VARIETY ADOPTION, EFFICIENCY AND WELFARE OF FARMERS IN SELECTED AGRO-ECOLOGICAL ZONES OF GHANA

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2021

DECLARATION

Student

I hereby declare that, this thesis is the result of my own work and to the best of my knowledge, it contains no material previously presented for the award of any other degree in this university or elsewhere except where due acknowledgement has been made in the text.

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ABSTRACT

In recent times, the government of Ghana is working intensely with its institutions and development partners to develop and disseminate improved tomato seed varieties (ITSV) to farmers to increase domestic production, with the broad objective to reduce tomato importation in the country. However, there is limited quantitative evidence on how the adoption of ITSV affects farmers' efficiency and well-being. Against this backdrop, this study examined the factors that influence farmers' adoption of ITSV, the impact of adoption on farmers' welfare, farmers' technical efficiency and marketing efficiency. A multi-stage sampling technique was used to select 508 farmers and 65 market players from three agro-ecological sectors for interview. Regarding the determinants of ITSV adoption and its effects on welfare, the study employed the multinomial endogenous switching regression (MESR) model to correct for possible selectivity bias problems. Based on field observation, the respondents were put into mutually exclusive categories which warranted the estimation of the multinomial logit in the first stage of the MESR. The categories were Techiman variety (traditional variety), Pectomer, Power Roma and Pectomer/Power Roma. The study employed the Metafrontier technical efficiency (MFTE) model to examine farmers' technical efficiency across the various agro-ecological zones. Similarly, the impact of tomato seed variety adoption on production efficiency was estimated using a stochastic metafrontier (SMF) model and propensity score-matching (PSM) technique to address self-selection bias. Marketing margins and the ordinary least squares (OLS) regression were used to analyse farmers' marketing efficiency and its determinants. Results revealed that the proportion of farmers who adopted pectomer was higher than those who adopted both pectomer and power roma, power roma alone and the local variety (Techiman). Results from the MESR model revealed that male farmers, relatively wealthy farmers who benefited from credit as well as farmers residing in Forest Savannah Transitional Zone (FSTZ) and those who perceived that improved varieties improved yields had higher probabilities of adopting ITSV over the local variety. Also, the adoption of ITSV improved household welfare. The findings of group-specific metafrontier technical efficiencies (MFTEs) and technical gap ratios (TGRs) showed that tomato farmers in Ghana produced below the group frontier due to limited and inefficient utilization of the available technologies. Farmers in FSTZ achieved higher mean technical efficiency than those in Coastal Savannah Zone (CSZ) and Guinea Savannah Zone (GSZ). Furthermore, the group-specific TE scores from the adoption of ITSV were higher than the group-specific TE scores from the adoption of the local seed variety. Specifically, farmers who adopted pectomer and both pectomer and power roma, had mean TE of 93.1% and 90.9% respectively, compared to 86.2% and 88.8%, had they not adopted. Land, seeds, insecticides, and tractor services positively influenced tomato production in GSZ, FSTZ and CSZ. Farmers who were: male; formally educated; belonged to FBO; and had access to extension services, were technically efficient in GSZ and FSTZ. In CSZ, female farmers and farmers producing tomato as a secondary occupation were more technically efficient. Marketing efficiency (ME) of farmers was higher than that of wholesalers but not as high as those of retailers. However, farmers had the least market power. The study recommends that research institutions such as CSIR and its affiliates should step up efforts aimed at increasing farmers' access to ITSV with high-yielding capability, tolerance to pest and bad weather. Efforts aimed at increasing tomato farmers' adoption of improved tomato varieties could be directed through trained extension agents and provision of credit to farmers. The Buffer Stock Programme should be strengthened to buy farm produce and stabilize prices so as to minimize exploitative power of market queens and retailers in the tomato value chain.

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DEDICATION

This work is dedicated to my dear parents Hajia Lawuratu Abukari and Alhaji Shafiwu Yorimah.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

ADB	Agricultural Development Bank
AE	Allocative Efficiency
AMA	American Marketing Association
ANOVA	Analysis of variance
CES	Constant Elasticity of Substitution
CM	Choice Modeling
CSZ	Coastal Savannah Zone
DADU	District Agricultural Development Unit
DEA	Data Envelopment Analysis
DF	Deterministic Frontier
df	Degrees of freedom
DIF	Diffusion of innovation
DMU	Decision Making Unit
EE	Economic Efficiency
ETGR	Environmental Technology Gap Ratio
EU	European Union
FAO	Food and Agriculture Organization
FBO	Farmer-Based Organization
FDH	Free Disposal Hull
FIML	Full information maximum likelihood
FSTZ	Forest Savannah Transition Zone
GARCH	Generalized Autoregressive Condition Heteroscedasticity
GDP	Gross Domestic Product
GLM	Generalized Linear Model

GSS	Ghana Statistical Services
GTC	German Technical Corporation
GSZ	Guinea Savanna Zone
ICOUR	Irrigation Company of Upper East
IFCSP	Integrated Food Crop System Project
IMF	International Monetary Fund
IMR	Inverse Mills Ratio
ITSV	Improved Tomato Seed Variety
LPM	Linear Probability Model
LRT	Likelihood Ratio Test
MESR	Multinomial Endogenous Switching Regression
META	Meta-frontier
ML	Maximum Likelihood
MoFA	Ministry of Food and Agriculture
MoTI	Ministry of Trade and Industry
NBSSI	National Board for Small Scale Industries
NER	North East Region
NGO	Non-Governmental Organisation
NPCs	National Product Classification for Services
NR	Northern Region
NSTC	Northern Star Tomato Company
OLS	Ordinary Least Squares
PRSV	Power Roma Seed Variety
PSV	Pectomer Seed Variety
QMLE	Quasi-Maximum Likelihood Estimator

RESET	Regression Equation Specification Error Test
SAPs	Sustainable Agricultural Practices
SDGs	Sustainable Development Goals
SFA	Stochastic Frontier Approach
SFSP	Sedimentary Farming System Project
SSA	Sub-Saharan Africa
SVA	Seed Variety Adoption
TE	Technical Efficiency
TGR	Technology Gap Ratio
TMS	Techiman Seed Variety
UER	Upper East Region
UK	United Kingdom
UNDP	United Nations Development Plan
UNSD	United Nations Statistical Division
UPA	Urban and Peri-Urban Agriculture
US	United States
WHO	World Health Organization
WTO	World Trade Organisation

CONVERSIONS OF UNITS

Standard Metric Units

1 kg	0.001T
1 T	1000Kg
1 ha	2.471acres
1 acre	0.404Ha

Standard Metric Units

1crate of tomatoes	72kg (From Ghana food pricing, Dec 2019)

CHAPTER ONE

1.0 Introduction

1.1 Background

Agriculture plays a vital role in the economy of many developing countries and serves as the largest employer of the labour force and a major contributor to foreign exchange earnings and national income (Davis et al., 2017). The multi-dimensional role of agriculture in achieving zero hunger and no poverty under the Sustainable Development Goals (SDGs) is well acknowledged especially after the sector contributed to reducing poverty and malnutrition at the end of 2015 in most developing countries (Food and Agriculture Organization [FAO], 2015). Agricultural output was also expected to double in most developing countries to match the growing demand for food, for human and livestock consumption and industrial purposes (Fan *et al.*, 2012; FAO *et al.*, 2019). A higher agricultural output can be achieved by improving productivity. However, increasing agricultural productivity, to a large extent, requires farmers to amend their production beyond rain-fed agriculture and traditional farming methods (Azumah *et al.*, 2019). Increasing agricultural productivity through the adoption of improved technologies and proper farm management practices would improve national and household food security, and contribute to poverty reduction and higher welfare (Valdés and Foster, 2010; Wiggins *et al.*, 2010; Biru *et al.*, 2019). Over the past five decades, food crop production performance has been satisfactory in many countries (FAO, 2013). While developed regions realise increased food crop production from yield increases and higher cropping intensity, less developed countries in sub-Saharan Africa (SSA) achieve growth in crop production through area expansion for agriculture (Ray *et al.*, 2012).

In Ghana, the agriculture sector is noted to have a more significant impact on poverty reduction than the service and industry sectors (International Food Policy Research Institute (IFPRI, 2013), as cited in Asuming-Brempong *et al.*, 2016). However, the sector in Ghana has over the last two decades relinquished its position as the principal contributor to the Gross Domestic Product (GDP) to the service sector, as its GDP contribution fell from 30.4% in 2006 to 19.3% in 2019, whiles that of the service sector increased from 48.8% in 2006 to 52.4% in 2019 (Ghana Statistical Service [GSS], 2019).

Small-scale farming accounts for more than 90 per cent of the economically active population in the rural areas of Ghana (GSS, 2014). Farmers involved in small-scale agriculture have limited access to assets that facilitate the transition from less productive farming to modern commercial farming. Compared to other countries worldwide in terms of agricultural productivity, Ghana still lags behind (Fugile and Rada, 2013). Invariably, certain obstacles exist that prevent Ghana's agricultural sector from realising its potential. The major causes of low agricultural productivity in Africa and for that matter Ghana have been identified to include socioeconomic, biophysical constraints, policy, and bad practices, among others (Ehui and Pender, 2005).

Crop production in Africa is still more vulnerable to climate change than in other continents (FAO, 2019). However, with the adoption of improved technologies and proper proportions and combinations of modern agricultural inputs, farmers will be able to increase crop output by improving yields. Adoption of new agricultural technologies in developing countries is always at the centre of policy interest. Despite the obvious benefits of many of the new agricultural technologies, including machinery and management practices, farmers fail to adopt them or adopt them late and thus miss some of the of advantages of technology adoption (Mottaleb, 2018).

In recent times, climate change impact in Ghana's agriculture has intensified. This impact is partly associated with erratic rainfall and makes it difficult for farm investment planning. Fruits and vegetable production bears the brunt of weather-related threats as it is largely practised by smallholder farmers under rain-fed production systems (Minot and Ngigi, 2004).

The term 'vegetable' refers to the tender edible shoots, leaves, fruits and roots of plants that are eaten whole or partially raw or cooked as an add-on to starchy foods and meats (Keraita *et al.*, 2007). Unlike other crops which are harvested for their seeds, roots and fibres at the mature stage, vegetables are harvested when the plant is still fresh and high in humidity and are known to enrich diets with good fragrance, taste and nutrients including lipids, carbohydrates and vitamins (Komolafe *et al.* 1980; Dittoh, 1992; Slavin and Lloyd, 2012; Amao, 2018). Vegetables have low starch content and are a good source of antioxidants, fibre and phytonutrients that promote good health and digestion. High intake of vegetables and fruits contributes to a reduction in premature mortalities from several chronic diseases. For this reason, a balanced diet meal should consist of fruits and vegetables. In a healthy diet, the required percentage of vegetables is 45% of the total diet and can complement the vitamins A, B, C, D, E, and K (Abdullai (2006)). Vitamin A preserves the health of respiratory and eye tissues; Vitamin B is important for the growth of the nervous system; Vitamin C maintains the health of blood cells and tissues; Vitamin D helps to preserve bone and dental health; Vitamin E promotes reproductive health and vitamin K is important for blood clotting and prevention (Abdulai (2006)). The high fibre content of vegetables is important for maintaining intestinal health as a diet low in fruits and vegetables causes' constipation. Beyond their nutritive values and health benefits, vegetable crops also provide income and employment for many farmers and traders in urban areas of developing countries (Abdulai *et al.*, 2017). In 2011, 1 billion tons of vegetables were produced exceeding fruits production by 0.1 per cent from about 1.1 per cent of the world's agricultural land (Food Outlook, 2012 cited in Abdulai *et al.*, 2017; FAO, 2013).

Tomato (*Lycopersicon esculentum*) is one of the popular and major income-generating vegetables cultivated by small-scale and medium-scale commercial farmers in the world (Dapaah and Konadu, 2004; Naika *et al.*, 2005; Osei et al., 2010; Ayandiji *et al.*, 2011; Singh *et al.*, 2018). Tomato has a shorter maturity period and a longer production period (usually up to a year), making it economically attractive to many farmers (Naika *et al.*, 2005). Tomato flourishes in temperate to hot and humid tropical under different crop systems and climatic conditions (Naika *et al.*, 2005). Compared to other vegetables, tomatoes are the most consumed vegetable in Ghana. It is consumed in large quantities daily by most households in various dishes such as soups, sauces and salads (Dapaah and Konadu, 2004; Attoh *et al.*, 2014). Tomato is an essential source of minerals (iron, phosphorus), lycopene, beta-carotene, vitamins (A and C), large amounts of water, and low calories (Naika *et al.*, 2005; Wilcox *et al.*, 2003; cited in Abdulai et al., 2017). Tomatoes help prevent ageing-related illnesses such as dementia and osteoporosis (Freeman and Reimers, 2010). They can also improve fertility in men by improving sperm quality and swimming speed by reducing the amount of abnormal sperm in men due to their high lycopene content (Innes, 2014).

The acreage of tomatoes was 4.3 million hectares in 2014, producing an estimated 162 million tonnes (FAOSTAT, 2014). The five largest producing countries are China, India, USA, Turkey and Egypt with China and India accounting for about 60 percent of global cultivated area and tomato output in 2014 (Heuvelink, 2018). USA, China, Italy, Spain and Turkey are largest producers of processed tomatoes, with the five countries accounting for about 85 per cent of the 41 million tonnes of global processed tomato in 2015 (Heuvelink, 2018).

In 2014, Africa's tomato production totalled 17.938 million tons in 2014, with Egypt leading the continent at 8.625 million tons (FAOSTAT, 2014).

In Ghana, tomato cultivation is a thriving agricultural activity in the savanna and forest-savanna transition zones. Differences in rainfall patterns and access to water make its production highly seasonal and bring about variations in harvest periods (Robinson and Kolavalli, 2010). Two periods (period of abundance and period of scarcity) are created due to seasonality and reflects in market prices (Ihle and Amikuzuno, 2010). Also high production costs, poor seed distribution, poor adaptation to a variety of climatic conditions, inadequate use of irrigation water when needed, sub-optimal and/or untimely application of inputs such as fertilizers, lack of access to credit and inadequate control of pests and diseases contribute to low yields and inefficiency of tomato production in Ghana. It is believed that a farmer can obtain the maximum attainable yield levels by using the recommended quantity of fertilizer, improved seeds and other relevant inputs in tomato production (MoFA, 2010).

1.2 Problem Statement

Since the end of World War II, governments in many developed countries have helped transfer agricultural technology to developing countries to improve agricultural productivity. Recently, the introduction of advanced agricultural technologies has become the focus of developing countries' political interests. The introduction of improved tomato varieties provides a significant increase in yields by reducing post-harvest losses leading to the creation of processing and export industries, thereby promoting economic development (Aidoo *et al.* 2014; Perez *et al.*, 2017). In addition to its ability to induce the transition from current low-productivity farmers and subsistence farming to commercial agriculture (Awideide *et al.*, 2016), adoption of improved agricultural technologies such as using improved seed varieties can also play a vital role in mitigating the malnutrition problem (Rashid and Anwar, 2001). Anang (2019) stated that adoption of improved technologies is particularly important in developing countries where productivity, efficiency gaps and production inefficiencies of smallholder farmers remain high.

Horticultural products such as tomatoes offer huge prospects for poverty reduction and export growth in Africa due to their increasing demand throughout the world (Anang *et al.*, 2013). The tomato industry contributes significantly to most West African farmers' nutritional status and livelihoods in the rural and peri-urban areas (Adenuga *et al*, 2013). In Ghana, it contributes significantly to the income of small scale farmers in the savanna and forest transition zones and mostly seen as an indispensable ingredient found across every region and used in the preparation of dishes such as soups, sauces and salads (Attoh *et al.*, 2014). Its production has increased over the years to meet the growing demand. Tomato production increased from 196,991 tons in 2000 to 381,015 tons (see Figure 1.1). Production was stable in the early 2000s until 2005 when the country reported a sharp decline in production from about 100,000 tons per year to around 50,000 tons per year. The variations in production were primarily due to changes in the area of cultivated land rather than output. Output grew virtually exponentially between 2008 and 2018, as shown in figure 1.1.

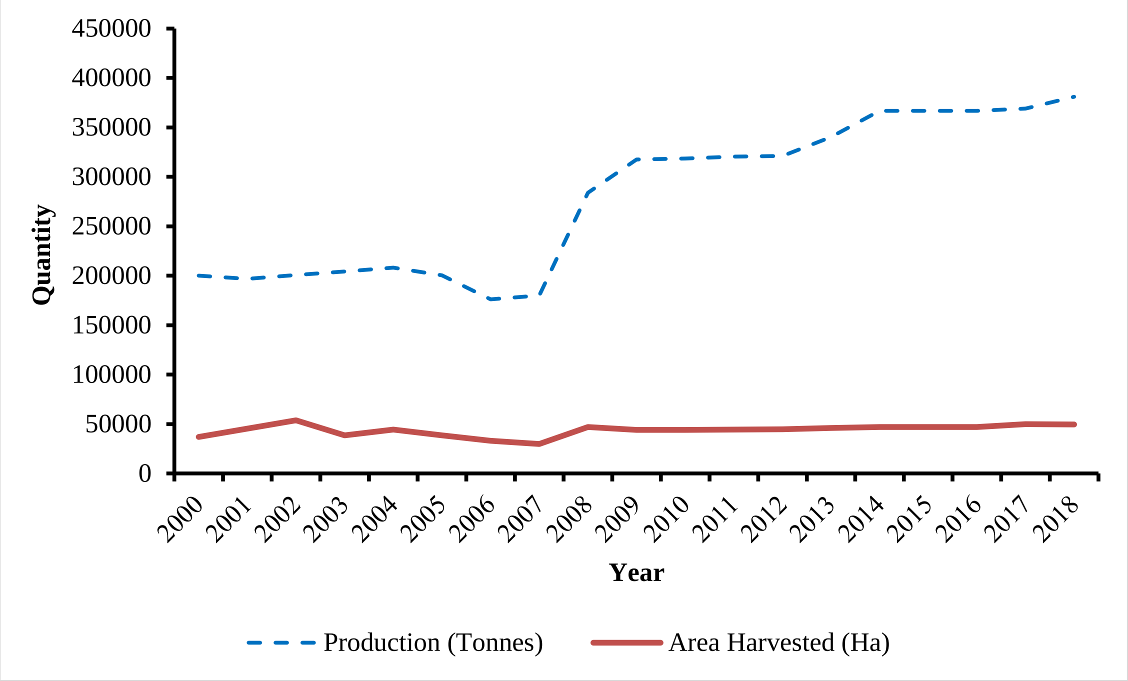

Figure 1. 1: Tomato production trends and yields

Source: FAOSTAT, 2018

Despite the increase in tomato production, the national demand for tomatoes has long outstripped domestic supply, a situation that attracts large imports from neighbouring countries (Dapaah and Konadu, 2004; Melomey *et al.*, 2019). In 2017, for instance, some 75,000 tonnes of tomatoes were imported to meet domestic demand. The supply shortfalls are attributed to low yields (Attoh, 2011), which are on average, between 63,500 kg/Ha to 65000 kg/Ha. Low agricultural productivity is partly due to resource-use inefficiency in agricultural production and low adoption of improved agricultural technologies, including crop varieties (Owusu, 2016). The over-dependence on rain-fed agricultural system and low adoption of farm inputs and improved technologies are among the major reasons for low rice productivity (Abdulai et al., 2018; Bidzakin et al., 2018; Mabe, 2018; Ragasa et al., 2013). In particular, the use of modern seeds and fertilizer is still below recommendation. It is reported that about 90 per cent of African farmers use local seeds for production (McMichael, 2013). For instance, Dankyi et al. (2005) reported that more than half of Ghanaian farmers use local seeds during crop production.

The use of local and poor-quality seed variety limits productivity (Mohiuddin et al., 2007) and the quality of tomato, affecting pricing (Horna *et al.*, 2007; Clottey *et al.*, 2009). Although the crop has many benefits, most developing countries, particularly those in Africa, face many challenges in cultivating it, rendering its production unprofitable.

Increasing tomato productivity will not only involve the transformation of some institutions such as the land tenure systems and input and credit provision; it will also require farmers to adopt improved technologies (Donkoh *et al.*, 2013).

Some recent studies suggest the need to explore initiatives that enable farmers to access available technologies such as improved tomato seed varieties due to their established positive effect on production efficiency. Using empirical evidence from the Tolon district of Ghana, Ahmed and Anang (2019), examined whether farmer based-organization (FBO) enhance technology adoption; Mutyebere *et al*. (2018) also evaluated the adoption of improved varieties and input elasticity among smallholder maize farmers in Kabarole District – Western Uganda; Shiferaw *et al*. (2014) assessed the effect of improved maize adoption on the food safety of small household maize producers in Ethiopia; Afolami *et al.* (2015) used primary data from rural households in southwestern Nigeria to assess the health effects of introducing improved cassava varieties.

Regarding technology adoption and welfare, it is argued that joint adoption improved technology increases household welfare as revealed by Abbeam and Baiyegunhi (2019) for cocoa farmers in Ghana, Khonje *et al.* (2018) for crop farmers in eastern Zambia; and Kassie *et al.* (2015) using maize farmers in Malawi. Similarly, a study by Euler *et al.* (2017), Abdulai (2016), Kabunga *et al.* (2014) and Asfaw *et al*. (2012) had a positive impact on technology adoption on household welfare and poverty reduction. These studies differ in terms of crops selected, models estimated and the factors considered as determining adoption or technical efficiency but are uniform in their conclusions on the effect of technology adoption on welfare and technical efficiency.

Efficiency measurement is continually an area of significant research in developing countries due to the inefficiencies in developing countries' production processes (Betty, 2005). For instance, some studies (e.g., Attoh, 2011) have delved into options for increasing tomato production in Ghana and others (e.g., Ahmed and Anang, 2019; Anang *et al.*, 2019) have unravelled the drivers of efficiency performances of tomatoes farmers. However, none of these studies were conducted across agro-ecological zones, let alone investigating the impact of improved seed adoption on production efficiency and farmers' wellbeing.

Also, despite the vast literature examining the factors that influence farmers' production efficiency in Ghana, very little empirical evidence exists on the impact of improved technology adoption on production efficiency of tomato farmers. Again it is worth mentioning that, adoption, efficiency and welfare studies are time, location and crop-specific; hence, the quest for this studies which differ interms of location, time, methodology and focus. Thus, the need for this study to delve further into improved tomato seed variety adoption and its effect on production efficiency, marketing efficiency and welfare of farmers in selected ecological zones of Ghana.

1.3 Research Questions

The key research question to be answered by the study is "What is the impact of improved tomato seed adoption on the welfare of farmers in selected agro-ecological zones in Ghana and how efficient are the actors?"

Specifically, the study sought to address the following research questions.

1. What are the levels and determinants of improved tomatoes seed variety adoption in the selected agro-ecological zones of Ghana?
2. What is the welfare impact of improved tomato seed variety adoption on farmers in the selected agro-ecological zones of Ghana?
3. What are the levels and determinants of technical efficiency of tomato farmers in the selected agro-ecological zones of Ghana?
4. What is the effect of ITSV adoption on the production efficiency of tomato farmers in the selected agro-ecological zones of Ghana?
5. What is the market efficiency of tomato marketers in the selected agro-ecological zones of Ghana?

1.4 Objectives of the Study

The main objective of the study was to determine the impact of improved tomato seed adoption on the well-being of farmers in selected agro-ecological zones of Ghana and to identify the technical and marketing efficiencies of the stakeholders.

Specifically, the study sought to:

1. Investigate the levels and determinants of improved tomato seed variety adoption of farmers in selected agro-ecological zones of Ghana.
2. Analyze the welfare impact of improved tomato seed variety adoption of farmers in selected agro-ecological zones of Ghana.
3. Determine the levels and the factors influencing the technical efficiency of tomato farmers in selected ecological zones of Ghana.
4. Estimate the effect of adoption of improved tomato seed variety on production efficiency of tomato farmers in the selected agro-ecological zones of Ghana.
5. Analyze the market efficiency of tomato marketers in the selected agro-ecological zones of Ghana.

1.5 Significance of the Study

This study seeks to provide detailed information on the determinants of improved tomato seed variety adoption and its impact on farmers' wellbeing, and marketing efficiency across the agro ecological zones. The research has relevance in the areas of academia, policy formulation and implementation as well as farming and agricultural extension delivery and advocacy. This is summarised below:

Policy makers need guidance on some of the factors that explain farmers' adoption of improved agricultural technologies such as ITSV. Although many interventions and studies have been conducted on adoption of improved agricultural technologies and its impact on production efficiency and wellbeing, there is a dearth of empirical evidence on the impact of improved tomato production on farmers' production efficiency and wellbeing. This study therefore attempts to bridge this gap by providing empirical evidence on not only the adoption of ITSV but also the production and welfare impacts of such adoption. This would help with the policy formulation relative to the growth and development of the tomato industry in the country.

Also, when the socioeconomic factors as well as policy and institutional factors that determine the productivity performances of farmers are identified, relevant recommendations will be made for policy makers to establish policies that can be implemented to improve upon tomato productivity levels. With this, farmers with low efficiencies will be able to bridge the gap through improvement in their management practices.

In addition, the findings in this study would assist extension officers by making them aware of some of the factors influencing farmers' adoption decision and the level of adoption of improved agricultural technologies, farm management practices and market access strategies.

Also, given the scale of tomatoes farming in Ghana, a defined market structure (i.e., identified market places) and price for tomatoes is relevant in helping to improve the marketing efficiency of actors in the tomato value chain. The findings of this study will help identify the price and marketing margins along the tomato value chain.

Finally, the findings of this study will add to existing literature and also serve as a reference material for other researchers and provide for further studies into related aspects of the topic area.

1.6 General Hypotheses

The study would test the following hypotheses based on the research questions:

RH_1: The null hypothesis states that socio-demographic and institutional factors do not have influence on the decision to adopt or not to adopt improved tomato seed.

RH_2 The null hypothesis states that the decision to adopt or not adopt improved tomato seed has no significant impact on household welfare.

RH_3: The null hypothesis assumes no significant differences in technical efficiencies of farmers in the three agro-ecological zones.

RH_4 : The null hypothesis assumes no significant differences in technical efficiencies of farmers cultivating traditional seed varieties and those cultivating improved seed varieties.

RH_5: The null hypothesis assumes no significant differences in market efficiencies of farmers in three agro-ecological zones.

The above hypotheses will be tested with the generalized maximum likelihood ratio test $\lambda LR = 2[L(H_i) - L(H_0)]$, where $L(H_I)\, and\, L(H_0)$ are the maximum values of the log likelihood functions under the alternative and null hypothesis respectively. The null hypothesis is rejected when $LR > \lambda \chi C^2$

1.7 Delimitations of the study

The study is limited to three agro ecological zones, hence may not provide a general view of tomato farmers in Ghana on the levels of adoption, determinants and impact of tomatoes production in the country.

Also, the study is based on wet season data, which may not fully capture the effects of variability in climate and market demand on production and marketing efficiencies. The findings of this study are also based on cross-sectional data, which do not capture the long-run effects of ITSV adoption on household welfare.

1.8 Organization of the Study

The thesis is organized into eight chapters: Chapter one covers the introduction, problem statement, research objectives and justification of the study. Chapter two briefly describes agriculture in Ghana, tomato policy, production and marketing in Ghana, while relevant theoretical and empirical review is presented in Chapter three. This includes details of economic, allocative and technical efficiency of tomatoes production, market margin and market power. The methodology is discussed in Chapter four and consists of model specifications, a description of the variables and the dataset used for the research. Chapter five contains an outline of the descriptive statistics based on the farm and farmer characteristics. Chapter six details the data analysis process on determinants of adoption of improved tomato seed variety, determinants of welfare and the impact on farmers using multinomial logit and the Multinomial endogenous switching regression models. Chapter seven of the study is also devoted to the presentation of the results on technical efficiency, impact of adoption on efficiency and marketing efficiency and its determinants using meta-frontier, marketing margins and ordinary least squares. Finally, Chapter eight summarizes the results, draws conclusions based on the finding, makes recommendations based on the conclusions and offers suggestions for future studies.

CHAPTER TWO

2.0 AGRICULTURE, TOMATO PRODUCTION, MARKETING AND POLICY IN GHANA

2.1 Introduction

This chapter presents a review of relevant literature on Ghana's agriculture, vegetable production and marketing, tomato production, processing and marketing policies of Ghana. The theoretical review covers tomatoes production globally and narrows down to Africa, West Africa and Ghana in particular. It also covers the morphology of tomato and its production challenges.

2.2 Agriculture in Ghana

Unlike other Ghanaian sectors, the agricultural sector is considered a major economic force that has a greater impact on poverty reduction. It is predominantly smallholder, traditional and rain-fed (GSS, 2017). Right from cultivation to final consumption, it serves as a source of livelihood to many who are engaged in it.

Over 90 percent of the economically active rural populations in Ghana work in smallholder farming (GSS, 2014). These smallholders have limited access to funds, which may promote the transition from low-income agriculture to modern commercial agriculture. In Northern Ghana for instance, over 70 percent of the economically active population are involved in agricultural activities (GSS, 2014). The major restriction to their survival is infrastructure and inadequate access to agricultural inputs and technology, and facilities for storing, processing and selling goods.

Historically Ghana's economy was dominated by the agricultural sector and accounted for more than 30 per cent of post-independence GDP. However, the sector has declined significantly in recent times and is now the third largest contributor to

GDP (GSS, 2019). In 2019 the share of agriculture in Ghana's GDP was 17.31 per cent, industry contributed approximately 31.99 per cent and the service sector contributed about 44.14 per cent (GSS, 2019)

Ghana also lags behind, in terms of world agricultural productivity, compared with other countries (Fugile and Rada 2013, World Ba nk 2013). According to MoFA (2013), some of the challengies faced by the agricultural sector in Ghana are poor infrastructure, including lack of attention to irrigation development, high transportation costs, poor roads to farms, land acquision, tenure issues and social and environmental problems. Also, Ehui and Pender (2005) described challenges such as socioeconomic, policy, biophysical constraints, and bad practices, as the key causes of low agricultural productivity in East Africa. In recent times, the effect of climate change on Ghana's agriculture has increased significantly. This effect is due to erratic rainfall which challenges farm investment planning. Fruits and vegetables production bears the brunt of weather-related risks because it is practiced, to a large extent, by smallholder farmers under rain-fed production systems (Minot and Ngigi, 2004).

2.3 Tomato Variety

Varieties of tomatoes are grown based on local conditions and cultivation intent. There are two known tomatoes varieties; local variety also known as land-races and improved (or commercial) varieties. The improved varieties are the products of continuous plant selection processes based on certain characteristics. Some of these characteristics include fruit color, plant form, fertility and pests and disease resistance. A farmer who aims to maximize profit selects varieties that perform best in terms of utility (profit) under local conditions

The F1-hybrids is one of the breeds produced by tomato breeding companies. It is grown from seeds that have been produced by controlled manual pollination of male and female parent lines combining high yield, disease resistance and other characteristics of plants and fruits. Unlike farmers in African countries, more than 40 percent of farmers in Asian countries predominantly grow the hybrid. New seeds should be purchased at each season when using hybrids. This may cost more money but the resistance means that tomato plants need less pesticide spraying. The yields are also higher, providing more possibilities for the tomatoes to be brought to the market.

Tomato varieties developed in Ghana have varying levels of resistance to pests and diseases. Resistant varieties have an inherent resistance to pest and diseases that is present in the seed. Varieties of resistance seeds are capable of preventing such unique diseases, meaning that it is very difficult or unlikely for a plant with these resistant features to get the particular disease. Resistance may be attributed to different characteristics of the plant. Densely covered leaves with hairs preventscertain insects from sitting on such improved trees. Again, some colors are unattractive to certain insect which gives such plants resistance ability. Most of these characteristics are noticeable, while features leading to fungal and virus resistance are invisible (Minot and Ngigi, 2004).

Local tomato varieties of unknown origin are cultivated mainly by farmers in lowland tropical Africa and the Caribbean. They have very sour and bitter fruit taste, thin, round or flat, with many parts, and are particularly suitable for grinding sauces with condiments. The local varieties, when cultivated, give better yield than most imported varieties under the intense rainy season with environmental stress (MoFA, 2010).

2.4 The Tomato Sector in Ghana

Compared to other countries, the tomato sector in Ghana is unable to fully utilize its potential in terms of production and yields as well as supporting processing companies. The sector has failed to improve the living conditions of households involved in its production and marketing (Anang *et al.*, 2013). Despite significant investment in the tomato sector by successive governments through the establishment of a number of tomato processing plants, the quality and quantity tomatoes needed for commercial processing are not cultivated with farmers' preferring the cultivation of local varieties with a high water content, seed counts, poor color, and low brix. Owing to seasonality production, high perishability, low market access, and competition from imports, most tomato farmers are unable to sell their tomatoes, which are left to rot in their fields (Ihle and Amikuzuno, 2010). On the other hand, farmers who continue to achieve higher tomato yields and make profits, continue to choose the cultivation of tomatoes over other crops (Ihle and Amikuzuno, 2010; Ghanaveg report, 2016). According to Ghanaveg report (2016), one of the key challenges for tomato farmers in Ghana is high per-unit input costs. Production cost, yields and prices of vegetables also vary across agro-ecological zones and between towns and cities. A lower average production cost per unit is needed to achieve a competitive agro-tomato processing in Ghana, so that farmers can sell their tomatoes profitably at low but guaranteed prices offered by processors (Dittoh, 1992; Anang *et al.*, 2013,).

2.4.1 Tomato Production and Marketing in Ghana

Tomato is a food and a cash crop in Ghana. Increasing competitiveness of tomato production can enhance economic growth in Ghana (Anang *et al.*, 2013). Despite its potential, tomato production continues to decline, while imports of tomato paste surge at high levels (Robinson *et al.*, 2012). The country is ranked as the second largest importer in Africa with about 7,000 Mt of fresh tomatoes and 27,000 Mt of processed tomatoes imported annually from the nabouring Burkina Faso and European market (MoFA, 2017).

Tomato, however, is one of the most significant revenue generating vegetables grown in Ghana. Tomato growing in Ghana is done throughout the year and in two tomato production systems. A rain-fed production system in Southern Ghana with a bimodal rainfall pattern and a dry season irrigated system in Ghana's Upper East Region (UER) with a uni-modal rainfall pattern. The rain-fed tomato crop is grown between June and November, while the irrigated tomato cultivation is between October and April. Tomato farmers in both the rain-fed and the dry season systems use labor-intensive technology at all stages of the production cycle (i.e., from planting, weeding, fertilizer application, spraying of pesticides and irrigation water application, harvesting to marketing. Despite the fact that tomatoes is one of the most important vegetables produced and consumed in the country, its production shows a pronounced seasonal trend with prices typically varying substantially even within a week.

Tomato enterprises offer great potential in creating employment opportunities and increasing incomes of actors involved in the tomato value chain through commercialization (Koenig *et al*., 2008). Unlike other types of SSA markets in which many small traders of different calibers are involved from assembling commodities at the farm gate to retailing, Ghana's tomato marketing mechanism includes relatively few traders with clearly specified activities. Tomato marketing occurs mainly at farm gates in originating markets while sales activities in both originating and consumer markets occur on market and non-market days, because the product is perishable. Ghanaveg. (2014) posited that, the number of supermarkets in Ghana is increasing with major plans by supermarkets such as Shoprite to increase the number of purchasing points in Accra, Kumasi, Takoradi and Cape Coast. It is expected that, the increase in the outlets will have a corresponding increase in demand for fresh fruits and vegetables. Presently, about two containers of fruits and vegetables are imported from Europe and Egypt weekly by Shoprite in Accra to supplement local supply (Owusu, 2012).

2.4.2 Ghana's Policy on Production, Processing and Marketing of Tomatoes

Presently, in order to improve on food security, Ghana's policy on agriculture is centered on increasing agricultural production and productivity (GSSP, 2010). To ensure that the amount of food needed to meet people's needs is given and increase the primary producers' net incomes, the policy focuses in creating a competitive private sector that can guarantee employment and increase income, with special focus on the rural poor (Gallat Associates, 2003). A baseline survey of 12 tomato growing areas in Ghana, conducted by the Horticulture Development unit and the Post-Harvest Services Administration in Ghana shows Ghana's government new interest in tomato production (GSSP, 2010).

Ghana's tomato production, processing and marketing policy explicitly supports and promotes the tomato sector with a specific emphasis on value creation and large-scale processing. However, tomato production and productivity policy have been less focused and less effort has been made to ensure profitable and competitive tomato production in the country so that tomato processors can provide the necessary inputs at competitive prices (GSSP, 2010).

Immediately after independence in the 1960s, as part of President Nkrumah's overall development plan, the Ghana Tomato Division actively participated in the establishment of many tomato processing plants (Ablorh-Odjidia, 2003). Three state-owned agricultural processing firms were established. They were: Pwalugu tomato factory in Pwalugu (Upper East Region), GIHOC - TOMACAN canned tomatoes in Wenchi (Brong Ahafo Region), and Nsawam (Eastern Region) cannery GIHOC. The combination of structural reforms pushed by the World Bank and the IMF in the late 1980s resulted in a shortage of spare parts and obsolete machinery, lack of technical capacity and financial management; and poor marketing. This resulted in continuous breakdown of the factories and led to a total closure of the factories (Ablorh-Odjidia, 2003). Many successive governments attempt to revive the Wenchi processor through a public-private partnership (PPP) failed. Recent efforts to restart the Pwalugu (Northern Star) processor in the Upper East region to resume domestic tomato processing on a large scale also failed. Under PPP's leadership in Ghana, four organizations sponsored a pilot project to assess the economic feasibility and sustainability of structured value chain relationships in the tomato industry; German Technical Cooperation Service, Africa Link Limited, Brong Ahafo Regional Office of the Ministry of Food and Agriculture and Unilever Ghana Limited. The project's aim was for public corporations to help farmers to grow fresh tomatoes for ALL to process into tomato paste and tomato pulp, and marketing and selling of the tomato by Unilever. The process started with the creation of the GTZ, working through the Ministry of Foreign Affairs to help farmers to pursue sustainable agricultural practices through the Sedentary Agricultural Systems Project (SFSP) (Ablorh-Odjidia, 2003). Although tomato yields increased, farmers had no market access during peak harvest seasons. At the Tono-Vea irrigation site in the Upper East region, Unilever conducted tomato trials with farmers and was optimistic that the varietal trial of tomato seeds would help encourage farmers to grow improved varieties to meet the demands of their processing plant in Tema. ALL became interested and acquired the Wenchi plant via debt-equity swap. Through informal discussions, an agreement was reached between the Ministry of Food and Agriculture and GTZ to assist farmers in growing tomatoes, to supply GTZ. In addition, Unilever indicated its readiness to package and focus on distribution and marketing of sold tomato paste under its TOMAROMA brand. A formal agreement was reached in February, 2002, in which GTZ donated €200,000 to the farmers for the management of the project for technical assistance. One half of GTZ contribution was used to fund the acquisition of 8% of ALL shares on behalf of the farmers through a Farmers Trust established for this purpose. In selected Districts, the Ministry of Food and Agriculture through the District Agricultural Development Units (DADU) have agreed to work with farmers. ALL and Unilever have donated at least €200,000 which will mostly be used for part of their initiative. Furthermore, Both ALL and Unilever had to cover more than €200,000 of the pre-existing costs and other financial related expenditures (GSSP, 2010). In order to achieve a yield of 20 tonnes per hectare, varieties were tested, farmers' organizations (FOs) were created and the necessary protocols were developed. An agreement was reached on loans to farmers, all through the ADB. The corresponding input data, fertilizers and seeds were also given to assist some farmers, especially those in the Dormaa district, who were denied the loan due to concerns over spin-off sales to the neighboring Côte d'Ivoire. ALL guaranteed all the loans to the FBOs and employed extension agents in the various districts and some national service workers to assist farmers in enforcing the new protocols (GSSP, 2010). Despite this strategy by ALL, it faced several difficulties in the production process. Plantation was delayed by the Agricultural Development Bank (ADB) delay in giving cash to farmers in three districts. Just at the vegetation level where water was necessary for tomato growth, most districts were hit by the July – August 2003 drought.

With the support of ALL, farmers were able to plant early and achieved an average yield of more than 17 tons / ha. At the peak of production, farmers were able and willing to supply ALL with tomatoes at a previously agreed processing price. However, when tomatoes became scarce and fresh tomatoes price went above the production price, farmers later diverted to the fresh market (MoFA, 2010).

Wenchi has not been working since the pilot and chose to focus on an alternative model of supplying the factory with tomato grown by ALL on 550 acres of land. The project aimed to grow tomatoes using irrigation in the dry season with shortagesmet by farmers' ad hoc purchases. There are proposals to include contract farmers once production and processing is stable. During this time, ALL has continued to work with five farmers and continues to share with them innovations and experiences. When farmers were ready and willing to deliver on their contracts, Pwalugu found problems with inadequate crates for tomato collection, weak transport network to go to the farm-gates, and insufficient cash to pay the farmers. The challenges experienced brought about lack of trust between farmers and processors hence the shutdown of Pwalugu once more (GSSP, 2010). Within 2009-2010 the National Association of Vegetable Producers worked through the Regional Minister to get the Pwalugu plant back on track. A committee composed of three members, ICOUR, MoFA and Northern Star, was tasked with the role of reviewing and recommending a strategy to revitalize the plant through the Parliamentary Agriculture Subcommittee. After analyzing the farmers' operating cost and crop estimates, the committee recommended purchasing tomatoes at GH ¢ 5.40 per 40kg box plus transportation cost from the farm gate. Several regional and ministerial visits to Pwalugu required the reopening of Pwalugu for the 2009–10 tomato seasons, which is located in the Upper East region (usually running from December to April). MoTI assured farmers of an operating factory at the end of 2009 with the goal of assisting farmers with credit in supporting Pwalugu's purchases of tomato. While the factory managed to begin processing in March, partially through the seasons of 2009-10, by which time farmers would have harvested already. But it was not clear how much was procured.

In November 1997, the UK Institute for Natural Resources (NRI) Integrated Food Crop Systems Project (IFCSP) and the Department of Bio-Chemistry of the Kwame Nkrumah University of Science and Technology, Kumasi under Ellis supervision, initiated a research into the production of tomato paste through low-cost and safe technologies. At Tuobodom near Techiman (Techiman Municipal Assembly) in Ghana, NRI and ADRA Ghana (Techiman Office) collaborated to scale up technology for tomatoes production. A small facility was constructed and actual experiments and production tests were carried out. The facility eventually was closed since the government does not agree to the small-scale manufacturing that is being found in the informal sector. In 1992, at the request of the Derma Vegetable Growers Association Limited UNDP/ILO/DRHC, under the flagship of the Department of Rural Housing and Cottage Industries, conducted a feasibility study on the establishment of a food processing plant for processing tomato at Derma, in the Tano south district of the Brong Ahafo region. The feasibility study concluded that there was enough local tomato demand to support the establishment of a processing mill (a multi-purpose juice extractor) of 1,200 liters/day (120 crates of 52kg tomato fruits) to produce paste and puree. During tomato off-season (March–June), other fruits such as mango and orange could be processed by the factory. Again, the feasibility study indicated a 76 percent internal return rate would be obtained. The mill would act as a service center where farmers can process their fruits. A further conversation with the NBSSI regional officer at Sunyani revealed that the project has originally been stalled due to lack of funds, although some processing equipment had been purchased and plant facilities had been built. Attempt to revive the project saw NBSSI seeking Commonwealth Secretariat assistance. A consultant who visited in 1997 and consulted on the partially constructed plant was supposed to have another consultant in 1998 to determine the project's economic viability, but the plant has never begun working to date (GSSP, 2010). The factory's operation was supposed to provide a ready market for tomato producers and also save tomato farmers from bumper harvests which would otherwise have gone bad due to lack of storage facilities.

The processing difficulties also included the fact that farmers were unable to provide the factories with the evaluated tomato varieties (H 3044 and H 7151) by H.J. Heinz Co continuously. Improving the processing of tomatoes in Ghana will increase foreign exchange earnings, give jobs and growth opportunities in the country's poor rural areas and also minimize the importation of tomato paste from other countries.

2.4.3 Challenges of Tomato Production in Ghana

Tomato production in Ghana is faced with numerous challenges. Studies by Dapaah and Konadu (2002) and Aidoo *et al.* (2014) summarized key challenges facing tomato farmers in Ghana. These challenges are discussed below in detail. From the literature, high production cost, lack of market, restricted access to credit, diseases, pest and weed control, land tenure and land acquisition problems, and irrigation facilities for dry season tomatoes as well as the accessibility of improved seeds for cultivation are identified as some challenges facing tomato production in Ghana. These are described briefly below.

High cost of production: This has been one of the main plagued to most tomato farmers in Ghana. The recent depreciation in the Ghanaian currency worsened the situation since the prices of items went skyrocketing. This constraint is as a result of high prices of factors of production such as fertilizer, pesticide, seed, tractor services, hired labor and irrigation facilities.

Lack of market: Sometimes, as a result of hard work and favorable weather condition, there is bumper harvest which leads to poor prices offered by Market Queens[i] for farmers' produce. Most often, due to the perishable nature of fresh tomatoes, farmers have no other option than to sell at lower prices to avoid their produce going waste. The challenge of nonexistence of guaranteed market and pricing system for tomatoes are major disincentives to production.

Limited access to credit: Most farmers in Ghana have little or no capital and find it hard to fund their own farm operations and hence financing farm operations is a major constraint on the production of tomatoes in Ghana. Farmers are also generally unable to access credit/loans from financial institutions mainly due to lack of the appropriate collateral security to support credit application. The risky nature of farming deters most financial institutions from giving out loans to farmers.

Diseases, Pests and Problems with Weed control: These are challenges that contribute to severe losses in both quality and quantity of produce. When diseases, pests and weeds are properly controlled, losses can be reduced and farmers can as well get real value for their money. The tomato yellow leaf curl virus is one major disease in tomato production which has the potential of causing up to 100 percent economic losses in tomato production in many tropical and subtropical regions if not controlled (Pico *et al.* 1996). Bacterial wilt also causes severe damages to tomato production coupled with the devastating effects of rodents (Hayward, 1991).

2.5 Vegetable Production in Ghana

The demand for vegetables production has increased rapidly in recent years as a result of greater appreciation of the nutritional importance of vegetables in the nation's food requirement. Besides its food value, it is very important for improving the economic condition of urban and rural peasants. Vegetables are high value crops with great export potential. However, their perishable nature, high resource consumption, and poor economic condition of farmers as well as lack of suitable market nearer to the production point discourage farmers from going into their production. Generally, farmers nearer to urban areas have relatively readily-available markets for their produce.

In Ghana, vegetable production is rapidly increasing food security and jobs, and serves as major economic activity in the forest and savanna areas, particularly among women (Braima *et al.*, 2010). The vegetable sector in Ghana has three distinct components: (1) commercial/market gardening areas found in major cities such as Accra, Kumasi, Takoradi and Tamale; (2) rural-urban relation where vegetables are produced in rural areas and purchased by market queens and transported by road to the cities; and (3) small domestic or backyard planting, where vegetables are grown for domestic use (Shafiwu *et al*, 2018).

The climatic condition for the production of vegetables in Ghana is quite favorable. The favorable climatic conditions allow vegetables such as in tomato (*Lycopersicon esculentum*); onion (*Allium cepa*); shallots (*Allium escalonicum*); okra (*Hibiscus* *esculentus*); eggplant (*Solanum melongena*); local spinach (*Amaranthus spp*.); Indian or Gambian spinach (*Basella alba*); sweet and chilli pepper (*Capsicum annuum*); and hot pepper (*C. frutescens*) to be cultivated (Abdulai, 2006). Yet, numerous factors prevent the production of vegetables in Ghana, including poor husbandry techniques; seed shortages; poor extension services; insufficient use of fertilizers; unreliable rainfall; inadequate irrigation facilities; lack of organized processing and marketing of vegetables; and consequently, low income from most of the crops during the normal growing season (Obuobie *et al.*, 2014).

There is a rising demand for exotic vegetables such as cabbage, carrot, lettuce and radish, eaten mainly by urban dwellers and non-Ghanaians. According to Ahowe *et al. (*2009), vegetable production for urban and peri-urban areas in Ghana is common in rain-fed upland ecologies. The average vegetable farmer operates on small scale from about 0.1ha to about 0.8ha (Nsiah-Gyabaah, 2003). Shocks caused by environmental stresses such as drought, pests and diseases are likely to intensify in the long run, resulting in low vegetable yields. It is estimated that pest and diseases kill as much as 45 percent of the world's crop which vegetables are not exempted (Bhanti and Taneja, 2007). In Ghana's agricultural sector, pesticides are massively used in preventing crop pests and diseases (Clarke *et al.*, 1997).

An increase in agricultural productivity is heavily dependent on its marketability. Advance Consulting LTD report (2016) noted that the emerging trend of Ghana's vegetable landscape paints an image of a robust sector that can generate urban and peri-urban growth, and make a significant contribution to the country's economy. Internally, the advent of supermarket chains and high-end restaurants and hotels offers a huge opportunity for increased vegetable production to feed an ever-increasing middle class with a healthy-eating search (GhanaVeg, 2014). Efficient market connects sellers and buyers in response to current supply and demand situation, and also plays a competitive role in boosting consumption of products that are critical element for economic growth (Haruna *et al*, 2012). In Ghana, fresh vegetables production is all year round and closely correlated with the unique weather conditions and market windows. GhanaVeg (2014) stated that irrigated agriculture is on the rise leading to new production areas around the Volta River and Lake Volta, as well as specific irrigated areas in and around Accra.

2.6 Conclusion

The review revealed that, tomato is a key commodity in the world and Ghana in particular. In Ghana, its farming is confined to three main agro-ecological zones and is one of the largest consumed vegetables. However, tomato production is inadequate and faces high post-harvest losses and the output risk in terms of marketing power. In addition, more of local seed varieties with high content of water are being produced with no specialized marketing systems, storage facilities, and limited processing plants. Also, it was found that, climatic and environmental changes, pests and diseases and low adoption of improved technologies are some of the factors affecting the production and yields of tomatoes in Ghana.

CHAPTER THREE

LITERATURE REVIEW

3.0 Introduction

This chapter reviews the theoretical and empirical literature on the study's thematic areas. It consists of four themes. The first section relates to the factors affecting farmers' decision making in the adoption of improved tomatoes seed variety and the impact of adoption of ITSV on welfare. The second section focuses on farmers' technical efficiency in the various agro-ecological zones and also the impact of adoption of ITSV on efficiency. The third section details the concept of efficiency, technical efficiency, metafrontier, measurement or approaches of metafrontier and relevant econometrics model related to the study. The final section relates to marketing efficiency and the determinants of marketing efficiency.

THEORETICAL REVIEW

THE CONCEPT OF ADOPTION AND MEASUREMENT

3.1 The concept of adoption

Decision making on technology adoption is a social cognitive process (Michelsen and Madlener, 2013). The decision to adopt a technology is based on the benefits derived from the adoption being greater than the benefits from the alternative option. Adoption does not involve the choice to accept an innovation alone but also the extent to which that innovation is integrated into the right context (Straub, 2009). This is on the basis of one's belief that the opportunity cost of taking the alternative decision is too high and significant. Rogers (2003) observed that, in reality, external factors such as sociocultural environment, economic factors as well as regulatory or institutional factors have the tendency of influencing one's adoption decision as a result of the deficiency in cognitive and normative decision models not capturing these extrinsically influencing factors. Rogers (2003) developed a diffusion model known as the Rogers' diffusion of innovation model (DIM) in which the diffusion of an innovation spreads through social communication processes, that is, factors extrinsically controlled but not intrinsically controlled. Rogers' DIM has been widely accepted due to its ability to systematically characterize innovation. Also, Rogers (1962) and Feder *et al.* (1985) classified stages of adoption of agricultural innovation into four stages. The stages were the awareness stage (hearing about the innovation), evaluation stage (collecting information about the expected benefits of innovation), trial stage (experimentation of the innovation) and finally, the adoption stage.

The awareness stage is the stage where farmers are sensitized on the innovations. In the sensitization or awareness stage, data is collected from the farmers and evaluated to know their perception about the expected benefits of the innovation (i.e., evaluation stage). During the trial stage, early adopters try to experiment to know whether the benefit of the innovations is better than the existing indigenous way of farming. Having realized the benefits of the new innovation out-performing their indigenous way of farming, they adopt the innovation.

After a while, other people within the social structure learn from the innovators (early adopters) and adopt the innovation. Over time, the number of adopters increases to the maximum and begins to decrease as some of the adopters stop adopting by going back to their old ways (Rogers, 2003).

The terms 'Adoption' and 'diffusion' were also distinguished by Rogers (1983). According to him, adoption involves the use of new or improved technologies (innovations) by a producer at a given time. On the contrary he defined diffusion as the process of communicating or transferring technology (innovation) from one person to another member of the society through specific channels or space over a period of time. The four elements in these two definitions are the improved technology (innovation), the communication channels, the social structure (members of the society) and the time period. The innovation needs to be communicated to the target group through channels like the mass media or face-to-face interaction. The choice of an appropriate channel is crucial. The characteristics of the target groups help in selecting the appropriate channel of communication and this defines the social structure. The appropriate time of delivery of the information about the innovation is also key. This is to ensure that the target population fully participate and understand the innovation.

3.1.1 Adoption Theories

Adoption is a complex process and an economic factor in production decisions. It begins with identifying a problem and searching for solutions. The next stage is the initial decision to try to adopt the solution implemented, whereas the final stage is the actual decision to try to get the solution (Mendel *et al.* 2008). Adoption is simply the decision to continue with a full or partial use of a technology (Wisdom *et al.*, 2013). The adoption process as explained by Greenhalgh *et al.* (2004) can be grouped into three: pre-adoption, peri-adoption, and established adoption. Pre-adoption is the initial stage of adoption where the decision-maker becomes aware of the technology. Peri-adoption is the continuous access to information about the technology, while established adoption relates to adopters' assurance to adopt the technology. At this stage, the individual would have developed an understanding and positive perceptions about the technology. Improved technologies are well recognized as having the potential to increase agricultural productivity and farm income or profits (Featherstone and Goodwin, 1993; Shields *et al.*, 1993; Busdieker-Jesse *et al.*, 2016; Anang, 2018; Takahashi *et al.*, 2019). The benefits of most improved technologies have been documented in Ghana and elsewhere. For instance, improved tomato seed variety is one of the production technologies promoted in Ghana in an effort to mitigate the negative impacts of low- and poor-quality yields in tomato production. However, there are some associated costs and institutional challenges, which could also impede the process of adoption. Napier (1991) and Pagiola (1994) reported that adoption of technology was limited by insufficient availability of resources, direct and indirect costs, and complexity. Studies generally argue that the adoption of a technology is related to its profitability, which suggests that adoption would only take place if it increases output value or if it allows farmers to shift to higher-valued crops at the least cost (Napier, 1991; Sain and Barreto, 1996).

Koundouri *et al.* (2006) proposed a framework for analyzing the conditions under which a farmer facing uncertainty about production and incomplete information would adopt a more efficient irrigation technique. Weyori *et al.* (2017) also analyzed the role of social network capital in improving the improved farm technology adoption. Hillmer (2009) in his systematic review of existing literature argued that technology diffusion and adoption could be explained using diffusion theories, user acceptance theories, decision making theories, personality theories, and theories of organization structure.

3.1.1.1 Diffusion Theories

Diffusion theories are theories used to explain how, why, and at what rate a defined community spreads new ideas and technologies. The commonly used theories of diffusion in the adoption literature are the Innovation Diffusion Theory (IDT) or Diffusion of Innovation Theory (DOI) developed by Rogers (1962) and Moore's (1995) Technology Lifecycle Theory (TLT). The IDT has been applied in the analysis of technology acceptance and adoption in various fields including health (Zhang *et al.*, 2015), nonprofit organization (Miranda *et al.*, 2016), banking (Dube and Gumbo, 2017) and agriculture (Tomaš-Simin and Jankovic, 2014). Rogers' theory of innovation is used to explain the process of diffusing an innovation over time among the members of a social system through certain channels (Rogers, 1995). According to the IDT, many factors can explain the behavior of the individual in the process of technology adoption, including their personal characteristics, social relationships, time factor and innovation characteristics (Padel, 2001). Rogers' theory of innovation is usually used to study the behavior of individuals when the researcher is interested in growth, change and adoption structure (Hillmer, 2009).

Technology Lifecycle Theory (TLT) focuses on the specifics of high-tech products marketing (Byers, 2006). This theory is a modification of the Roger's innovation theory. Moore's theory includes a gap in Rogers' bell-shaped innovation categorization, called "chasm" among early adopters and the early majority. The "chasm" refers to discontinuous technologies which are not in-tandem with existing processes, values, understandings and which are therefore subject to a variety of different perceptions and interpretations. However, because this theory ignores, to some extent, social networks and perceived technological attributes, it involves the role of specialized knowledge experts and ensures that such knowledge holders become intermediates in a process of diffusion.

3.1.1.2 User Acceptance Theories

Vankatesh *et al*. (2003) stated that User Acceptance Theories (UAT) are commonly adopted in the academic world and used in explaining user intentions to adopt information technology. These theories include; Theory of Reasoned Action (TRA) (Ajzen and Fishbein 1973, 1975), Theory of Planned Behaviour (TPB) (Ajzen, 1991), Technology Acceptance Model (TAM) (Davis, 1989), Motivational Model (Vallerand, 1997). Theory of Reasoned Action (TRA) describes the behavior of an individual as a function of behavioral intent of the attitude of the person. "Attitude" and "Behaviour" is defined by (Fishbein and Ajzen, 1975), as the result or intention of the individual's evaluation of an object. TPB is similar to the TRA, but includes perceived behavioral control as a third deterministic factor of behavioral intent. Perceived behavioral control recognizes the influence of perceived lack of ability to control the execution of behavior (Compeau *et al*., 1999) and it is also determined by control beliefs and perceived power (Bright, 1993). Unified Theory of Acceptance, and Use of Technology (UTAUT) was also developed as a result of a meta-analysis of eight existing models for accepting technology, with the aim of capturing their essential elements (Vankatesh *et al.* 2003). A conceptual model on the determinants of behavioral intent and user behavior was also developed in UTAUT. According to the authors, behavioral usage behavior is determined by behavioral intent and facilitating conditions while behavioral intent to use a technology is determined by performance expectation, effort expectation and social influence. The theory also assumes that there are moderating factors such as demographic variables (e.g., gender and experience) which influence behaviour intention to use a technology. Fred Davis in 1986 introduced the Technology Acceptance Model (TAM) which he adapted from the Theory of Reasonable Action. In 1989, Davis used TAM to model the general determinants of individual computer usage behavior. Two specific beliefs were included and tested in the TAM model: Perceived Usefulness (PU) and Perceived Ease of Use (PEU). PU is defined as the subjective probability of the potential user that the use of particular system will improve their action while PEU refers to the degree to which the potential user expects the target system to be effortless (Davis, 1989).

3.1.1.3 Decision-Making Theories

The theories of decision-making (DMT) are concerned with finding the best decision to take on the basis of the objective and the criteria of decision. A clear sequence in theory of decision making is firstly to understand the problems and set the goals. The second stage is that the decision-maker appraises a variety of alternative solutions and course of action while the individual collects data in the third stage and assesses the likely future outcomes of each alternative. In the final stage, the individual weighs the pros and cons of the given technology in question. Examples of DMT includes: Rational Choice Theory (RCT)/Game Theory (GT), Decision Making under Uncertainty (DMU), Risk Management (RM), Change Management (CM), and Media Richness Theory (MRT) (Daft and Lengel 1984). DMT, particularly the RCT is based on the premise of the maximization of individual utilities. RCT assumes that an ideal decision-maker is one who is fully informed, capable of calculating with perfect accuracy and is completely rational. Another assumption is that the individual will maximize the technology’s profit or expected benefits (Hillmer 2009). Among those alternatives the rational actor chooses the action which maximizes or yields greater utility.

3.1.1.4 Personality Theories

Personality theories are applied to identified technological change behavior of individual. These theories address various attributes of personality or traits that are said to have influence on reactions to disruptive or discontinuous technology. Example of a theory of personality is Social Cognitive Theory (SCT), (Compeau, and Higgins 1995).

3.1.1.5 Organisational Structure Theories

Organizational Structure Theories (OST) incorporates theories that relate behavior in accepting technology to the cultural structure or values of organization. The popular organizational structure theories are Schumpeter Innovation (Heertje 1981) and the Disruptive Technology Theory (Bower and Christensen 1995).

This current study, like others, applied the Rogers (2003) diffusion of innovation model (DIM). The Rogers' diffusion of innovation model (DIM) is a diffusion model in which innovation spreads through social communication processes, that is, factors extrinsically controlled but not intrinsically controlled. Hence in this study and as observed by Rogers the decision of a farmer to adopt an ITSV could be influenced by both internal and external factors such as sociocultural environment, economic factors as well as regulatory or institutional factors. Rogers (2003) diffusion model has been widely accepted due to its ability to systematically characterize innovation.

3.2. Measurement of Adoption

Analyzing the factors influencing farmers' adoption of improved production technologies and the effects on technical efficiency and welfare requires the estimation of a regression model. Traditionally, OLS, discrete choice models such as the standard Probit and Logit models, Linear Probability model (LPM), Multinomial regression models, Multivariate regression models and Ordered regression models are used to analyze adoption or categorical decisions to adopt a technology. Some of these models are explained below.

3.2.1 Ordinary Least Squares Technique (Linear Regression)

In establishing a relationship between a continuous dependent variable (tomatoes production), and independent variables (age, sex, farm size, farming experience among others), the most appropriate technique to adopt is Ordinary Least Square, if all the assumption are met (Allen, (1994) and Bergantino, et al (2020)). The linear regression model uses the OLS technique to estimate continuous variables when all Gauss-Markov's assumptions about the model, explanatory variables and the error term are binding. The OLS estimator tries to minimize the error term so as to produce unbiased, consistent and efficient estimates. Under the problem of inter-dependency between the error term and the independent variable, the OLS estimator ceases to be "blue". The basic estimator in the OLS technique is the linear regression model. It consists of both the simple linear and the multiple linear regressions. It is used on the basis of the dependent variable measured as a continuous variable and an approach for modeling the relationship between a dependent variable and one or more explanatory variables, which are mostly referred to as covariates (Lang 2013). It is used for fitting a predictive model to a set of given data values and a structural interpretation which permits for hypotheses testing. This thesis used the multiple linear regression models to estimate the determinants of marketing efficiency.

3.2.2 Linear Probability Model (LPM)

A situation where a dependent variable is dichotomous (i.e., two responses), the application of linear regression is not feasible. The most appropriate model to adopt is either the binary Probit or Logit models (Hailu, M., *etal* (2020) and Scarpato, D et al (2017)). The Linear Probability model (LPM) and binary Probit or Logit models are used to model a binary decision of adopting or not to adopt a given technology. The LPM uses the OLS technique to estimate binary choice variables. The coefficients of the model are interpreted as probability even though the parameters are linearly related to the dependent variable (Amemiya, 1981; Maddala, 1983). However, the LPM has several defects which make it inappropriate. First, its estimated probabilities do not fulfill the zero-one interval and in addition, produces constant marginal effects (Maddala, 1983; Capps and Kramer, 1985).

3.2.3 Probit vs. Logit Models

Unlike the LPM which fails to account for the zeros, the standard Probit and Logit models employ the maximum likelihood estimation (MLE) technique in estimating regression parameters and thus accounts for the zero compared to the LPM which uses the OLS estimator. A key feature distinguishing the standard Probit model from the Logit model is their link or distribution functions. The standard Probit model adopts the standard normal distribution function while the Logit model adopts the logistic distribution function. These two distribution functions enable the estimated probabilities of the standard Probit and Logit models to fall within the zero-one interval and also allow for non-constant marginal effects (Wooldridge, 2002;

Maddala, 1983). In view of this, the standard Probit and Logit models are mostly used to analyze farmers' adoption of improved technologies and production decisions involving only two categories. One may choose the Logit model over the Probit model due to the fact that the computation of the logistic distribution is simpler than the computation of the standard normal distribution function (Amemiya, 1981). The estimated probabilities of the Logit model can also be transformed into odds ratio which have straight-forward interpretations rather than the Probit estimates (Maddala, 1983).

3.2.4 Multiple Choices (Categorical Dependent) Regression Models

While multinomial regression models are employed for discrete variables with more than two categories which are uncorrelated and mutually exclusive, multivariate regression models are employed for discrete variables with more than two categories which are correlated (Chib and Greenberg, 1998). Multiple choices (categorical dependent) regression models are appropriate with multiple decisions where events are interdependent, independent, mutually exclusive or ordered. The multiple choices models include Multinomial regression models, Multivariate regression models and ordered regression models. Multinomial regression models, Multivariate regression models and ordered regression models are used to analyze categorical or multiple-choice dependent variables with multiple outcomes. Ordered regression models on the other hand, are applied to discrete categories that are ordinal and finite in nature (Wooldridge, 2002; Maddala, 1983).

Multivariate regression is method used to measure the degree to which more than one independent variable (predictors) and more than one dependent variable (response), are linearly related (Xu & Craig, 2010; Chib & Greenberg, 1998). Multivariate regression caters for the correlation of the error terms using rho and also enables us to determine whether certain variables are substitutes or complements using the signs of rho. For instance, if the coefficient of rho is significant, it means that the decision to adopt one technology has a relationship with the adoption of another technology. This implies that the estimated coefficients would have been biased and inconsistent if individual binary logit models were employed in the analysis due to the interdependencies. Also, a negative coefficient of rho indicates that the technologies are complements and a positive sign shows that they are substitutes.

Multivariate regression differs from the multinomial models in that it does not obey the assumption of the independence of irrelevant alternatives (Choo & Mokhtarian, 2008; Greene 2003).

3.3 The Concept of Impact Evaluation

Empirical evidence in many research documents has suggested that the impact of adoption of agriculture technology on farmers is enormous (Ndoro et al., 2014; Bezu et al., 2014; Khonje et al., 2015; Danso-Abbeam et al., 2018). Assessing the impact of such improved technologies on livelihood outcomes such as productivity, incomes, food and nutrition security, using non-experimental or observational data can be taken for granted. This is because of the significance of finding the counterfactual impacts of the adoption (Asfaw et al., 2012; Khonje et al., 2015). In adoption data, the outcome variable for adopters, if they had not adopted cannot be observed. In experimental data, the treatment is assigned randomly to the target group, while another group serves as a control or untreated. This is to ensure that the potential outcome variable observed in the treatment group without treatment is a statistical representation of what would have happened with treatment (Shiferaw et al., 2014;

Amare et al., 2012). Also, adoption of improved agriculture technology cannot be done randomly because it is the voluntary decision of the farmers to adopt or not based on the assessment of the improved technology. Thus, farm households who decide to adopt the improved technology (ITSV) and those who decide not to adopt may be systematically different (Amare et al., 2012). Now, assuming the potential outcome variable of interest, output of farmers (Yi) is a linear function with vector of covariates such as demographic characteristics, policy variables, to estimate the impact of adoption of agriculture technology (ITSV) on the output variable (efficiency and welfare), we include the adoption variable denoting one (1) for those who adopted and zero (0) for those who did not as an explanatory variable and apply OLS estimator. However, this approach cannot be relied on to produce unbiased and consistent estimates because of three fundamental flaws, namely; self-selection bias, endogeneity and missing data. This problem of self-selection bias contributes to the challenges of evaluating the impact of an intervention on potential outcome variable in observational data (Shiferaw et al., 2014). To accurately estimate the intensity of the effects of any intevention, the treatment should be randomly assigned such that the only difference between them is the treatment status (Danso-Abbeam and Baiyegunhi, 2018). Moreover, some characteristics that may influence farmers' decision to adopt an improved technology may also have the potential to affect the outcome variable of interest. Thus, the error term of the treatment status and that of the outcome variable may correlate, leading to endogeneity (Teklewood et al., 2013). These factors that affect farmers' decision status and the outcome variable of interest may come from observed and unobserved covariates (motivation, values, managerial skill, etc.). There is also a problem of missing data for the counterfactual outcomes due to the fact that the variable of interest can only be observed one state at a time (Wooldridge, 2003).

Thus, only the potential outcome of the participants can be observed but the potential outcome had they not participated cannot be observed (i.e. the counterfactual scenario).

3.3.1 The concept of sample selection and endogeneity

Researchers often use inclusion or exclusion criteria to include or remove respondents with certain characteristics from the study. This non-randomized selection process is pervasive in impact evaluation studies where one group is more likely to be included in the study than another. Respondents, on the other hand, may choose to participate in a programe or leave the study for a reason. When this happens, it creates non-response cases and missing data in the outcome variable, leading to sample selection bias. If selection bias occurs in an intervention study, it is preferably called known susceptibility bias (Hegedus and Moody, 2010). According to the authors, selection bias leads to overall effect sizes and or inaccurate results, as the intervention is examined in a less representative sample population. Nour and Plourde (2019) adds that sample selection bias occurs when the study population is not representative of the target population, so that the risk-benefit measure does not accurately reflect the target population. Sample selection bias occurs as a result of a non-random sampling design and other reasons explaining why some respondents choose to participate in a programme and others do not. Arnett and Claas (2017) explained that selection biases occur when comparing groups in an analysis that is either anonymous or intentionally different. Selection bias arises when there is systematic difference between the characteristics of those selected for study and those not (Henderson & Page, 2007). Selection bias often leads to inaccurate estimates (Lewis-Beck et al., 2004). Heckman (1979) is among the pioneers who identified and corrected for this problem in impact evaluation studies.

3.3.2 Impact evaluation techniques in Agricultural technology adoption

In evaluating the impact of an improved technology, many studies have used regression models like Heckman treatment effects, Tobit, double-hurdle correlated random effects and fixed effects models (Smale and Mason 2014; Ehiakpor et al., 2016; Baiyegunhi et al., 2018; Danso-Abbeam et al., 2018). The challenge with these models is that though they are able to correct for selection biases and endogeneity, they lack the capacity to predict the counterfactual outcomes. The main econometric models to deal with the three key issues of impact evaluation in cross-sectional data are Propensity Score, Generalized Propensity Score, Endogenous Switching Regression, and Conditional Mixed-Process (CMP). The Propensity Score Matching (PSM) is a non-parametric approach that uses matching technique to match treated against the control group based on observed characteristics. Endogenous Switching Regression uses instrumental variable approach where valid instrumental variables are used to identify the equation. PSM accounts for only observed characteristics while ESR accounts for both observed and unobserved characteristics. The PSM and IV methods are the two prominent techniques usually found in literature. Below is the detailed explanation of the some of the impact models.

3.3.2.1 Heckman Selection and Treatment Effect Methodologies

The Heckman Sample Selection model was introduced by Heckman (1979) on the basis of wage offer functions assuming that some wage data was missing as a result of missing observations on labor force engagement. It is a selection model for estimating a standard Probit model to generate an inverse Mill’s ratio (IMR) which becomes an independent variable in the main equation in the second-stage (Musah *et al,* 2014). Relatively, it is a simple technique for sample selectivity bias correction. It is argued by Wooldridge (2002) that, in the selected sample the selection bias is viewed as an omitted variable and corrected by the Heckman model. It consists of two equations which should be estimated in two stages. The first equation is referred to as the selection equation and estimated using a probit model.

The Probit Model predicts the likelihood of a particular household participating/adopting or not participating/adopting and also estimates what is known as the IMR. The IMR accounts for sample selection in the study so that the estimates would be unbiased (Musah *et al,* 2014). The second equation is called the equation of the outcome. It is estimated using the OLS. The OLS estimation is done with the inclusion of the IMR as a regressor. Both the first and the second models incorporate the same variables except that the second model incorporates a few other variables suggested by Wooldridge (2006) as variables for exclusion restrictions.

There are some drawbacks to the Heckman model of selection. For example, the exclusion restriction of the model is defined based solely on distributional assumptions (Sartori, 2003). Winship and Mare (1992) also found that the model was very sensitive to the assumption of bivariate normality. Again, Sartori (2003) observed that in some typical applications the *rho* parameter is also very sensitive. Aside these lapses, the model is limited to situations where the treatment variable is dichotomous or binary choices and therefore not applicable to multiple choice situation.

3.3.2.2 The Two-tier/Double Hurdle Models

The double-hurdle model is an econometric framework used on the assumption that households make two decisions concerning the adoption of technology, each of which is determined by a different set of explanatory variables. The Model was developed by Cragg (1971). Lijia *et al*. (2011) stated that, Cragg initially proposed the double hurdle model as a generalization of the Tobit model by allowing for the possibility of factor to have different effects on the probability of acquisition and the magnitude of acquisition. Olwande and Mathenge (2012) hold that the two-tier/hurdle models are often referred to as censored regression model sometimes also known as corner solution outcome.

The double-hurdle model when applied to any study divides the study analysis into two steps/stages: The first stage is the discrete likelihood of participation model and the state of participation decision and requires a probit estimation while the second stage is the decision on the strength of participation which also takes different functional distributions (Olwande and Mathenge, 2012). While the simplest two step models assume lognormal distribution in the second stage, a truncated normal distribution is assumed by the double hurdle of the Cragg. Because of the ability of truncated normal distribution to nests the Tobit model it is seen as superior over the lognormal. The truncated model allows the testing of the restrictions implied by the Tobit hypothesis against the two-step model (Olwande and Mathenge, 2012). The double hurdle model is more applicable in theoretical terms than other two-tier models. The fundamental difference between the Heckman model and the double hurdle model is in the second stage estimation. Whereas Heckman model estimates an OLS equation in the second stage the double hurdle model estimates a censored regression, usually a truncated regression. The principal flaw of the two-tier double hurdle is its requirement for all observations to be producers of a particular crop. Again, the effects of a given policy on marketing behavior are under-estimated by the double hurdle model (Burke and Jayne (2011).

3.3.2.3 The Tobit Model

The Tobit model was introduced by Tobin in (1958). It is a one-step approach. The Tobit model differs from the double hurdle model in the sense that it does not consider the first stage binary choice that deals with the participation decision. The limitation for considering only the Tobit model in a one-step approach is the assumption of same set of parameters and variables determine both the probability of adoption and the rate of adoption (Alene et al., 2008, and Wan and Hu, 2012).

3.3.2.4 Propensity Score matching technique

One of the widely used techniques in measuring the impact of agrarian intervention programme or innovation on an outcome variable of interest is the PSM. The PSM is a non-parametric estimation approach that does not require specification of any functional form and a random error term distribution. This estimation approach is theoretically appealing because it enables the comparison of the impacts of a treatment on the potential outcome of the treated and the control group (Heckman and Vytlacil 2005; Amare et al., 2012). The fundamental principles of the PSM are to match the treated group against the control with regard to a predicted propensity of being treated conditioned on some observed covariates (Rosenbaum and Rubin 1983; Wooldridge 2003; Heckman and Vytlacil, 2005). There are two critical assumptions underlying the estimation of impact using the PSM. The first assumption is the Conditional Independence Assumption (CIA). According to the CIA, the decision to be treated is a random condition on some observed covariates (Abadie and Imben, 2006; Takahashi and Barrett, 2013). Thus, given some observed characteristics of the respondents, the potential outcome and the treatment status in the absence of treatment are statistically independent (Takahashi and Barrett, 2013). The second most important assumption in PSM is the Common Support Assumption (CSA). The

CSA states that there should be a considerable similarity in observed characteristics between participants and non-participants of a programme. Thus, respondents being compared have equal probability of belonging to the treated and the control group (Amare et al., 2012; Takahashi and Barret, 2013). If these two assumptions are met, then the magnitudes of the effects of the treatment on the treated called the average treatment effects on the treated (ATT) can be validly estimated (Smith et al., 2005; Wossen et al., 2015). The ATT can be defined as the differences in the mean of the potential outcome of the treated group with and without treatment defined within the region of common support. The PSM technique follows a two-step estimation procedure. First, the treatment variable is modeled as a choice dependent variable using probit or logit after which the propensity for each observation is calculated. Second, each treated sample is matched with non-treated sample with same or similar propensity score value and the ATT are estimated (Abadie and Imbens, 2006). One drawback of the PSM is that it cannot account for hidden biases, it can only correct for observed heterogeneity to the extent that they are accurately estimated (Oduol *et al.*, 2011; Amare *et al.*, 2012).

3.3.2.5 The Endogenous Switching Regression technique

Another econometric technique that is designed to deal with the problem of observed and unobserved biases, endogeneity and missing data of the counterfactuals is the Instrumental Variable (IV) Approach, specifically the Endogenous Switching Regression (ESR). The IV approach has been used over the years to estimate the treatment effects of intervention programmes or agricultural technology adoption (Imbens and Angrist, 1994; Abadie, 2003; Abadie and Imbens, 2006). The approach usually requires a functional form and distributional error term (Abadie and Imbens, 2006). The fundamental assumption underlying the IV approach is that there must be at least an instrument that significantly affects the treatment status but not significant in explaining the potential outcome(s). In the IV framework, the techniques to estimate the average treatment effects include the Local Average Treatment Effect (LATE) and the latest econometric technique known as the ESR technique. A local average treatment effect (LATE) requires that minor restrictions are imposed by a wide range of models and economic circumstances. That is, to estimate LATE, making assumptions about the distribution of the outcome variable or that the treatment effect is constant may not be necessary (Oduol et al., 2011). As a result, if there is/are no available control group(s), the average treat effects on the target population can still be estimated (Oduol et al., 2011). Another econometric challenge in measuring impact is the use of treated samples and the control samples. The ultimate question is whether treatment should be assumed to exhibit an average causal effect across the whole population samples as proposed by the traditional instrumental variable approach such as Heckman Treatment Effects and the Two-Stage Least Square (2SLS). That is adoption of improved tomatoes seed variety is assumed to have impact on the outcome variable (Efficiency, Household Income, Asset and Expenditure) by way of constant shift as noted by Alene and Manyong (2007). When estimation is done by way of pooled sample, then the assumption is that the sample characteristics have similar causal effects (common coefficient) on both treated and control groups. This suggests that participation in an intervention programmed will have an intercept shift effects, and will always be the same, regardless of the covariates determining the value of the potential outcome (Alene and Manyong, 2007). Nevertheless, in many empirical studies, this may not be the case (Teklewood *et al.*, 2013b; Shiferaw *et al.*, 2014). This situation instigates the use of ESR to deal with the problem of intercept shift. In ESR analysis, separate equations are specified for both treated and the control groups, while accounting for endogeneity that may arise from sample selection bias. The ESR hypothesizes that factors of production are likely to have different impacts on the outcome variable of interest (Shiferaw et al., 2014). The ESR also permits interactions between treatment status and other explanatory variables in the outcome equation.

3.3.2.6 Endogenous Treatment for Count Data Models

Sometimes, there are situations in econometrics in which one wants to estimate the effects of a potential dichotomous treatment on an outcome variable of interest which is count in nature (count data). In the agricultural context, we may be interested in the effects of technology adoption (improved tomatoes seed variety adoption). In these situations, technology adopted (improved tomatoes seed variety) may be potentially endogenous. The effects of ITSV on the outcome variables (Efficiency, household income, household expenditure and household assets) may also have the problem of sample selection bias. In situations like this ignoring sample selection will result in inconsistent and biased estimates of the treatment variables (Improved tomatoes seed variety) resulting in wrong policy. Analyzing the impact of treatment variable of interest on outcome variable which takes the form of count data is, however, very rare in agricultural economics literature.

3.3.2.7 Multinomial Endogenous Switching Regression Model

The multinomial endogenous switching regression (MESR) model was proposed by Bourguignon et al. (2007) and has been applied in recent empirical studies (e.g. Di Falco and Veronesi, 2013; Teklewold et al. 2013; Ng'ombe et al. 2017). The MESR model has been widely used to measure the effect or relative impact of adopting two or more improved technologies or the effect of participating in two or more mutually exclusive projects/ interventions (Kassie *et al.* 2014).

Maddala and Nelson (1975) stressed that the MESR is a two-stage regression-based method used to model two outcome equations, one for treatment and one for comparison, enabling selection in treatment to be endogenous. The first stage of the MESR model uses a multinomial logit model to investigate the determinants of adoption while the second stage uses OLS to separately analyse the determinants of welfare in each of the category of adopters and nonadopters in the sample.

First stage Multinomial adoption selection model (MNL) of the MESR

Relative to this study, the first stage of the MESR model involved the estimation of a multinomial logit model to identify the socio-economic factors, influencing tomato farmers' decision to adopt a specific ITSV. A rational consumer/producer aiming to maximise output/profit assumes to choose among the different improved tomato varieties that yield maximum output. Utility obtained can be decomposed into observed and unobserved components (Greene, 2003). It is expressed as:

$$U_{ij}(X_{ij};Z_{ij}) = V_j(X_{ij};\beta) + \varepsilon \qquad \textbf{[1.0]}$$

Where: $U_{ij}(X_{ij};Z_{ij})$ is the utility of i^{th} individual choosing alternative j while ;$V_{ij}(X_{ij;}Z_{ij})$ denotes the deterministic component of the utility.

Multinomial logit is used to model the deterministic part. Following Greene (2003); Cameron and Trivedi (2005), Mpuga (2008) and Eneyew (2012), the conditional probability of the Multinomial logit model is specified as:

$$prob(Y_i = j / X_i) \frac{\exp(x_i \beta_j)}{\sum_{j=0}^{k} \exp(x_i \beta_j)} \qquad \textbf{[2.0]}$$

Where j=1, 2…k. The base category is used to compare other choices by restricting the base category's parameters to all zero ($\beta = 0$). The estimation of the Multinomial logit is by maximum likelihood method. The log-likelihood function is expressed

$$\ln L = \sum_{i=1}^{n} \sum_{j=1}^{k} d_{ij} \log(p_{ij}) \qquad \textbf{[3.0]}$$

The multinomial logit is interpreted in terms of odds. The odd of outcome *m* versus outcome *n* given *U* shown by $wm / n(U_i)$ is expressed as:

$$wm / n(X_i) = \frac{pro(y_i = m / X_i)}{pro(y_i = n / X_i)} = \frac{\ell(x, \beta_m)}{\ell(x, \beta_n)} \qquad \textbf{[4.0]}$$

Simplifying equation (4) gives

$$wm / n(X) = \ell(x, \beta_m - x, \beta_n) = \ell[x, (\beta_m - \beta_n)] \qquad \textbf{[5.0]}$$

Taking the natural logarithm of equation [5], the multinomial logit is expressed as linear in logit: $\ln[(wm / n(X_i)] = X_i (\beta_m - \beta_n)$ **[6.0]**

Equation [6.0] gives the effect of *X* on the logit of outcome *m* against outcome *n*. Also, the partial derivatives of the equation [6.0] give the marginal effects expressed as:

$$\frac{\partial \ln[wm / n(X_i)]}{\partial X_k} = \frac{\partial X_i (\beta_m - \beta_n)}{\partial X_k} = \beta_{km} - \beta_{kn} \qquad \textbf{[7.0]}$$

Where $\beta_{km} - \beta_{kn}$ means, for a unit change in x_K the logit of outcome *m* versus outcome *n* is expected to change by $\beta_{km} - \beta_{kn}$ units.

Second stage (outcome) model of Multinomial endogenous switching regression

Following similar impact studies by Abdulai and Huffman (2014), Kassie et al. (2015b), this study applied a MESR regression model developed by Bourguignon et al. (2007) to estimate the impacts of adoption of ITSV on farmers' welfare in the second stage. In the case of welfare, household expenditure, total household income and total household assets were used as proxy variables. Using OLS method, the inverse mills ratio (IMR), also known as the selectivity correction term is added to the outcome model. Rubio (2017) explained IMR as the standard normal density ratio, ϕ, which is divided by the standard normal cumulative distribution function Φ.

For a *MESR*, the *ith* farmer's choice decision is denoted by unobservable selection criterion function *I**. *I** is a latent variable that acts as a function of a vector of certain socio-economic determinants (D). In line with the work of Noltze *et al.* (2012), the sample selection criterion function for the *ith* tomato farmer in the *kth* agro-ecological zone is given as:

$$
\begin{array}{l}
1\ iff\ U_{1i}^{*} > U_{mi}^{*}\ or\ U_{1i}^{*} - U_{mi}^{*} > 0 \\
\vdots \quad \vdots \quad \vdots \qquad\qquad\qquad \vdots \\
\vdots \quad \vdots \quad \vdots \qquad\qquad\qquad \vdots \\
J\ iff\ U_{ji}^{*} > U_{mi}^{*}\ or\ U_{ji}^{*} - U_{mi}^{*} > 0
\end{array}
\quad j \neq m \qquad \textbf{[8.0]}
$$

Where U_m =utility of adoption of ITSV m, U_j =utility for adoption of ITSV j

A farmer chooses *jth* seed variety of tomato over that of *mth* if the utility he/she will derive from choosing *jth* seed variety is greater than adopting the *mth* seed variety of tomato. The model for the selection/adoption or non-selection/non-adoption not adopting a *jth* ITSV is expressed as:

$$U_{ji}^{*k} = A_i^k \omega_j + \eta_{cj}^k \quad \textbf{[9.0a]}$$

$$U_{mi}^{*k} = A_i^k \omega_m + \eta_{ci}^k \quad \textbf{[9.0b]}$$

Where A_i^k is a vector of exogenous or explanatory variables of the *ith* farmer's choice in the *kth* agro-ecological zone, ω_j and ω_m are the vectors of parameters, η_{ci}^k is the error term for the *ith* farmer in the *kth* agro-ecological zone of the selected sample. Following McFadden (1973), η_{ci}^k is assumed to be identically and independently Gumbel distributed; $N(0,\sigma_c^2)$ indicating the likelihood of a farmer *i* choosing a *jth* seed variety package from the multinomial logit model and given as:

$$P(U_{j1i}^* - U_{mi}^* > 0 / A_i^k) = \frac{\exp(A_i^k \omega_j)}{\sum_{m-1}^{m-J} \exp(A_i^k \omega_m)} \quad \textbf{[10.0]}$$

Note: Variables are as defined in equation [9.0]

The second stage of MESR involves the estimation of the impact of tomato seed variety adoption on specific explanatory variables for adopters of any of the following (PSV, PRSV, PSV/PRSV and TMSV). For non-adopters (TMSV) $j = 0$ while for adopters (PSV, PRSV and PSV/PRSV), $j = 1,2,3$ respectively. The outcome equations for various ecological zones are express as:

$$Zones(TMSV \Rightarrow I = 0 : TY_{0i}{}^K = \rho_0 H_i^k + \varepsilon_{0i}^k \qquad \text{if } j = 0 \quad \textbf{[11.0a]}$$

$$Zones(PSV, PRSV, PSV/PRSV \Rightarrow I = 1 : TY_{1i}^{K} + \rho_1 H_i^k + \varepsilon_{1i}^k$$
$$\vdots \qquad \text{if } j = 1,2,3 \quad \textbf{[11.0b]}$$
$$\vdots$$
$$Zones(PSV, PRSV, PSV/PRSV \Rightarrow I = J : TY_{ji}^{k} + \rho_j H_{ji}^k + \varepsilon_{ji}^k$$

where $TY_{0i}^k, TY_{1i}^k and TY_{2i}^k$ represent the outcome variables of the *ith* tomatoes farmer adopting (PSV, PRSV, and PSV/PRSV) tomatoes seeds. H_i^k represent a vector of exogenous variables that affect the outcome variables and $\rho_0, \rho_1 and \rho_2$ are vectors of parameters in the three zones. Also $\varepsilon_o^k, \varepsilon_1^k and \varepsilon_2^k$ denote the error terms for the three zones and are assumes to be distributed normally, that is $N(0, \sigma_0^2)$.

Following Maddala (1983), the sample selection equation error term η_{ci}^k, is assumed to have a correlation with the error terms of outcome equations (ε_0^k , ε_1^k and ε_2^k). Also, the expectation of the error term in the selection criterion model (η_0^k) is non-zero and this violates an assumption of classical linear regression that the mean of the error term must be zero. Hence, the use of OLS to estimate the parameters would result in inconsistent estimates. It is also assumed that the error terms ($\varepsilon_0^k, \varepsilon_1^k$ ε_2^k and η_0^k) have trivariate common normal distribution with a zero mean vector and non-singular variance-covariance matrix and this was specified by Fuglie and Bosch (1995) as:

$$Cov(\eta_c^k, \varepsilon_0^k, \varepsilon_1^k, \varepsilon_2^k) = \begin{bmatrix} \sigma_c^2 \sigma_{oc} \sigma_k \\ \sigma_{0c} \sigma_0^2 \sigma_{J0} \\ \sigma_k \sigma_{J0} \sigma_J^2 \end{bmatrix} \qquad \textbf{[12.0]}$$

Where σ_c^2, σ_0^2 and σ_J^2 are the variances of the error term of the sample selection equation η_c^k and are assumed to have a correlation with the error terms of outcome equations ε_0^k and ε_J^K. σ_{0c} is the covariance between ε_0^k and η_c^k; while σ_k denotes the covariance between ε_0^k and η_c^k; and σ_{J0} is the covariance between ε_j^k and ε_0^k σ_0^2 is also assumed to be 1 since ω can only be estimated on the scale factor 1 (Maddala, 1983; Greene, 2008). Notably, it is impossible to observe any given farmer's productivity performance indices in the various zones simultaneously, making it impossible to define σ_{Jc} and σ_{J0}. As the outcome equation is calculated by the adoption selection criterion function, this means that the selection equation error term is associated with the error terms in the outcome equations. According to Fuglie and Bosch (1995) the expectations of ε_j^k and ε_0^k are non-zero and can be expressed:

$$E(\varepsilon_{0i}^k / I_i^k = 1)E(\sigma_{0c}\eta_{ci}^k / I_i^k = 1) = \sigma_{0c}\frac{\phi\delta A_i^k}{\varphi\delta A_i^k} = \sigma_{0c}\lambda_{oi} \quad \textbf{[13.0a]}$$

$$E(\varepsilon_{0J}^k / I_i^k = 0)E(\sigma_{Jc}\eta_{ci}^k / I_i^k = 0) = \sigma_{Jc}\frac{\phi\delta A_i^k}{1-\varphi\delta A_i^k} = \sigma_{Jc}\lambda_{Ji} \quad \textbf{[13.0b)}$$

Where ϕ and φ are standard normal probability density distribution function and cumulative standard normal distribution function respectively. The λ_0 and λ_J indices are evaluated at δA_i^k known as IMRs.

One can use a two-stage procedure where the IMRs are incorporated into the outcome equations but this provides less efficient estimates. A full information maximum likelihood (FIML) method developed by Lokshin and Sajaia (2004) which estimates the selection and outcome equations simultaneously provides more efficient estimates.

Therefore, this study uses the full information maximum likelihood (FIML) method developed by Lokshin and Sajaia (2004) which is assumed to be an efficient estimate of selection and outcome equations simultaneously.

Following Akpalu (2012), should the covariances of σ_{0c} and σ_{Jc} be statistically significant, then the decision of not adopting any of the seed variety and the welfare impact are correlated and the null hypothesis of lack of selectivity bias is rejected, signifying the presence of endogeneity.

To be able to apply the FIML endogenous switching regression, the restriction criterion requires that there should be identification or instrumental variable, this means that at least one variable that affects selection decisions of seed variety by a farmer must not directly affect any of the farmers' output. Following the works of Kabunga *et al.* (2011) and Tambo and Wünscher (2014), FBO and Member of insurance policy are used as instruments for endogeneity correction.

These variables were used as instruments following literature, intuition and falsification test. Intuitively, FBO is seen as a platform for adoption of improved agriculture technology, hence belonging to an FBO would have a direct relation with adoption but may have indirect relation with welfare. In the case of Membership of insurance company, a farmer who has insured his or her product would fill secured and hence does not fear adopting a new technology, knowing in the event of failure he/she would be covered. On the contrary, insuring ones' farm is not a gurantee for a better life (welfare), thus it could be deduced that, insurance has a direct relation with adoption but has an indirect relation with welfare.

3.3.2.8 Conditional Expectations and Average Treatment Effects

The multinomial endogenous switching regression model could also be used to compare observed and counterfactual productivity performance (TY). The basis for comparison is the use of unbiased average treatment effects on the treated (ATT) for adopters and average treatment effect on the untreated (ATU) for non-adopters. It is used to compare the expected productivity performance (TY) of a farmer who adopted any ITSV (PSV, PRSV, PSV/PRSV) against a situation where the farmer did not adopt any of the ITSV but rather the traditional variety (TMSV) Consequently, it compares the expected productivity performance (TY) of a non-adopter, traditional variety (TMSV) producers to a situation of if s/he adopted an ITSV (PSV, PRSV, PSV/PRSV)

3.3.2.8.1 Respondent with adoption (actual adoption observed)

For adopter i in kth agro-ecological zones with H vector of explanatory variables, the expected value of productivity (TY) can be expressed as:

$$\begin{aligned} &E(TY_{1i}^{k} / I = 1)\rho_1 H_i^k + \sigma_{1c}\lambda_{1i} \\ &E(TY_{2i}^{k} / I = 2)\rho_2 H_i^k + \sigma_{2c}\lambda_{2i} \\ &\vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \\ &E(TY_{Ji}^{k} / I = J)\rho_J H_i^k + \sigma_{Ji}^{k}\lambda_{Ji} \end{aligned} \quad [14.0a]$$

3.3.2.8.2 Respondent without adoption (counterfactual)

For adopter i in kth agro-ecological zone with H vector of explanatory variables, the expected value of productivity (TY) had he/she not adopted any of the ITSV (i.e the traditional variety (TMSV))can be expressed as:

$$E(TY_{0i}^{k} / I = 1)\rho_0 H_i^k + \sigma_{0c}\lambda_{1i}$$
$$E(TY_{0i}^{k} / I = 2)\rho_0 H_i^k + \sigma_{0c}\lambda_{2i} \quad \text{[14.0b]}$$
$$\vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots$$
$$E(TY_{0i}^{k} / I = J)\rho_0 H_i^k + \sigma_{0c}\lambda_{Ji}$$

ATT measures the change (effect) in Output (TY) of the farmer due to adoption. It is the benefit that an adopter gets if he/she adopted and it is the difference between equations 14.0a and 14.0b.

3.4 Conditional Expectations and Average Treatment Effects

Following the works of Carter and Milon (2005), Di Falco and Veronesi (2014), and Teklewold et al. (2013), and the impact literature (Heckman et al., 2001), we described how multinomial endogenous switching regression model can be used to compute the counterfactual and average adoption effects (ATT) after the second stage. The counterfactual is defined as the potential adopters have they decided not to adopt whiles the actual, are the potential adopters who have actually adopted. The counterfactual is then compared with the actual. The basis for comparison is to use the average treatment effects on the treated (ATT) for adopters and average treatment effect on the untreated (ATU) for non-adopters. In this study, we compared the expected productivity performance (TY) of a farmer who adopted any of the packages (PSV, PRSV, PSV/PRSV) against a scenario that he/she does not adopt any of the improved packages (TMSV). We then calculated the ATT by comparing the outcome of the treated farmers household (the actual outcome) and their counterfactual outcome (the outcome of non-adopters). These outcomes are then compared using the T-test.

THE CONCEPT OF PRODUCTION/EFFICIENCY AND EFFICIENCY MEASUREMENT

3.5 The Concept of Efficiency

Kumbhakar *et al.* (2015) defined production as the transformation of resources (inputs) into finished products (outputs) and display a relationship between inputs and output levels given a specific technology. A production function could also be explained as the technical relationship that describes the limit of output achievable from each combination of inputs (Kumbhakar et al., 2015). This process increases consumer utility of agricultural produces. Mathematically, this can simply be shown as: $Y = f(l,k)$ with Y being the maximum output attainable, l (Labour) and k (Capital) are assumed to be the only inputs. These technical inputs in agricultural production may extend to land and other capital inputs such as fertilizer, seeds and pesticides, immaterial inputs as well as mechanization and weather variables. Theoretically, each producer is assumed to convert these factors into an output that matches a certain frontier. However, wrong combination of inputs and entrepreneurial wastefulness (through lack of managerial expertise) often tend to limit the producer's ability to reach the frontier. The level of efficiency is necessary in determining the returns on investment in production. Economists are in general, interested in production efficiency which explains how much of the producer's actual output falls below the frontier due to technical inefficiency, given inputs and technology. The output-oriented measure or input-oriented measure may be used to Technical efficiency (Kumbhakar *et al.,* 2015). The output-oriented TE is reached if the producer realizes the maximum attainable output given inputs and technology while the input-oriented TE is reached if the producer observes frontier output using fewer inputs. The motive behind the introduction of new technology (ITSV) to farmers is to improve productivity by employing fewer inputs to obtain maximum output. On this basis this study employed the input-oriented measure to evaluate tomato farmers' production efficiency.

The two-basic means of estimating a production function for efficiency analysis are the statistical and non-statistical approaches also known as econometric or programming approach (Johns, 2006). According to Kumbhakar *et al.* (2000), the statistical or the econometric approach addresses a distributional assumption, a functional form and distinguishes the effect of random measurement error from the inefficiency component outside the control of the farmer whereas the non-statistical approach such as the data envelopment analysis (DEA) does not make assumptions about the distribution of inefficiencies or the functional form of the production function. Therefore, it imposes certain technical restrictions such as monotonicity and convexity.

3.6 Measurement of Efficiency

Efficiency measurement was introduced by Farrell (1957) and is described by Kumar and Gulati (2010) as a measure of operational excellence in the resource utilization process. It can also be defined as how a farmer uses resources in optimal way to maximise production of goods and services. Closely related to efficiency is productivity. Productivity in its simplest form is determined by dividing the output realised by the total physical inputs or resources (land, labour, seed etc.) utilised. In other words, productivity is simply efficiency in production (Syverson, 2011). Single-factor productivity also measures or reflect units of output produced per unit of a particular input. Failure to obtain this potential maximum output results in inefficiency. The neoclassical economists defined production as the maximum achievable output per available resources to the farmer based on the concept of efficiency. If the production unit of this parameter is far away from the frontier (production or cost), it is considered to be inefficient (Oliver, 2015).

A firm in the production process is likely to experience some components of productive efficiency, namely: technical, allocative and economic efficiencies, which can be derived from the production and cost functions. Discrepancies in output between farmers can be explained by the differences in efficiency. Thus, the production frontier is associated with the maximum level of output obtainable given the minimum level of inputs required to produce a particular output. In other words, for each input mix the production frontier is the locus of the maximum attainable output.

Technical inefficiency: is attributed to a failure of the farm to produce the frontier level of output, given the quantities of inputs (Kumbhakar, 1994). The level of technical efficiency of a given farmer is determined by the relationship between observed production and some ideal or potential production (Greene, 1980). Its measurement is based on deviations in the observed output from the best or most efficient farmer in production. Consequently, inefficiency arises when the observed output lies below the frontier.

Allocative efficiency: is a firm or farmer's ability to use inputs in their optimal way, given their respective prices (Uri, 2001). If a farmer fails in allocating inputs at minimized cost, given the relative input prices, then there is allocative inefficiency or resource misallocation. The implication is that, misallocating resources will result in increased cost of production and hence decreased profit which is the ultimate goal of every firm. Failure to optimally allocate resources results in increased costs and reduced profit. Again, if the marginal rate of technical substitution between any two inputs is not equal to the resulting proportion of factor prices, a firm or farmer is said to be allocatively inefficient. This could be associated to sluggish adjustment to price changes and regulatory challenges (Atkinson and Cornwell, 1994). In the production process, a farmer may be technically efficient but allocatively inefficient; allocatively efficient but technically inefficient; both technically and allocatively efficient; and at worse, technically and allocatively inefficient. Economic efficiency seeks to pool technical and allocative efficiencies to depict the ability of a firm or farmer to produce output at possible minimum cost, given input price and a set of inputs. Consequently, achieving technical or allocative efficiency is only a necessary but not a sufficient condition for economic efficiency. A firm or farmer must at the same time achieve both technical and allocative efficiencies if it is to attain economic efficiency. These three concepts can be explained diagrammatically following Coelli *et al.* (1995) as depicted in Figure 3.1 below.

Following Farrell (1957), assuming that the farmer uses two inputs Z_1 and Z_2 and produces an output X , and that the production technology is a linearly homogeneous function of production. The frontier unit isoquant for this technology and an inefficient production activity are denoted by KK' and point A respectively. Along the ray OA, the production activity denoted by B and defined by the intersection of line segment OA with the isoquant KK', represents a technically efficient input combination as it lies on the frontier isoquant.

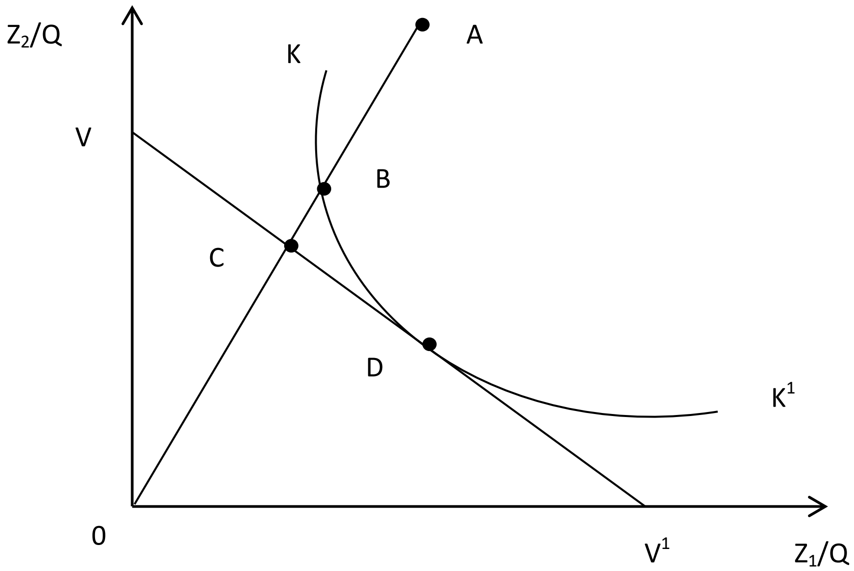

Figure 3.1: Diagrammatic representation of Technical, Allocative and Economic efficiency. Source: Coelli (1995)

The distance BA represents the technical inefficiency of the producing farmer at point A, simply because it is the amount by which both inputs could be reduced proportionally to produce the same output. It is usually written as the BA/OA ratio in percentage term. The farmer's technical efficiency of operating at point A is expressed as:

$$TE = \frac{OB}{OA} = 1 - \frac{BA}{OA} = 1 - TI \quad (0 \leq TE \leq 1) \qquad \textbf{[15.0]}$$

where, TI is technical inefficiency.

Point B shows that farmer fully operating efficiency because it is found on the efficient and frontier isoquant with technical efficiency of one. Given that competitive factor markets and the relative factor prices are $p = (p_1, p_2)$, the isocost line is VV' while point D corresponds to cost-minimizing of combination of inputs. Point A denotes farmers' allocative efficiency and is expressed as:

$$AE = \frac{OC}{OB} \quad (0 \leq AE \leq 1) \qquad \textbf{[16.0]}$$

The distance AC represents cost of production and could be reduced if the farmer produces at point D and thus becomes both technically and allocatively efficient (Khai and Yabe, 2011).

Generally, economic efficiency *(EE)* also known as cost efficiency is defined as the product of measurement of technical and allocative efficiency. It is expressed as:

$$EE = TE \times AE = \frac{OB}{OA} \times \frac{OC}{OB} = \frac{OC}{OA} \quad (0 \leq EE \leq 1) \qquad \textbf{[17.0]}$$

The measurement of efficiency by Farrell is originally characterized by constant returns to scale but has been generalized to less restrictive technologies by Färe and Lovell (1978) and Forsund and Hjalmarsson (1979).

An economically efficient production process is understood as one in which factor costs are minimized (allocative efficiency) and production occurs on the technological frontier (technical efficiency). Economic efficiency measurement is a combination of technical and allocative efficiencies (Richetti and Reis, 2003).

Economic Efficiency: Failure to produce the maximum output at a minimum cost from a given input mix results in inefficiency. Inefficiency could be due to lack of knowledge, limited access to technology, inadequate contact with agricultural extension agents, an inappropriate production scale and sub-optimal allocation of resources.

Two different methods have been widely used in establishing efficiency levels. These methods are non-parametric techniques (data envelopment analysis) and parametric techniques (stochastic frontier approach). Both approaches come with their weaknesses and strengths. Thus, debates on the superiority of one approach over the other has not received consensus till date. Stochastic frontier approach (SFA) used in the current studies has at least two advantages over nonparametric approaches. Firstly, nonparametric methods assume that the variations in firm performance are all associated to inefficiency. This assumption is problematic because measurement errors, omitted variables and exogenous shocks are ignored. Secondly, hypothesis tests can be performed for parameters estimated by parametric methods (SFA) and thus allows testing the fitness of the model. Ibgekele (2008) stated that, the main disadvantage associated with the use of parametric techniques is its constraints on the observed datasets by imposing a functional form. Meanwhile, efficiency measurement also depends heavily on whether the functional form reflects the reality or not. Farrell (1957) in his seminal work on efficiency pioneered the development of these different approaches to efficiency measurement. Figure 3.2 shows the measured of efficiency using both parametric and non-parametric approaches. The parametric methods of measuring efficiency consist of the Stochastic Frontier Analysis (SFA) and the Deterministic Frontier (DF) while the non-parametric approaches involve the use of Free Disposal Hull (FDH) and Data envelopment analysis (DEA). Both parametric and non-parametric approaches analysis uses either the input-oriented efficiency or output-oriented efficiency.

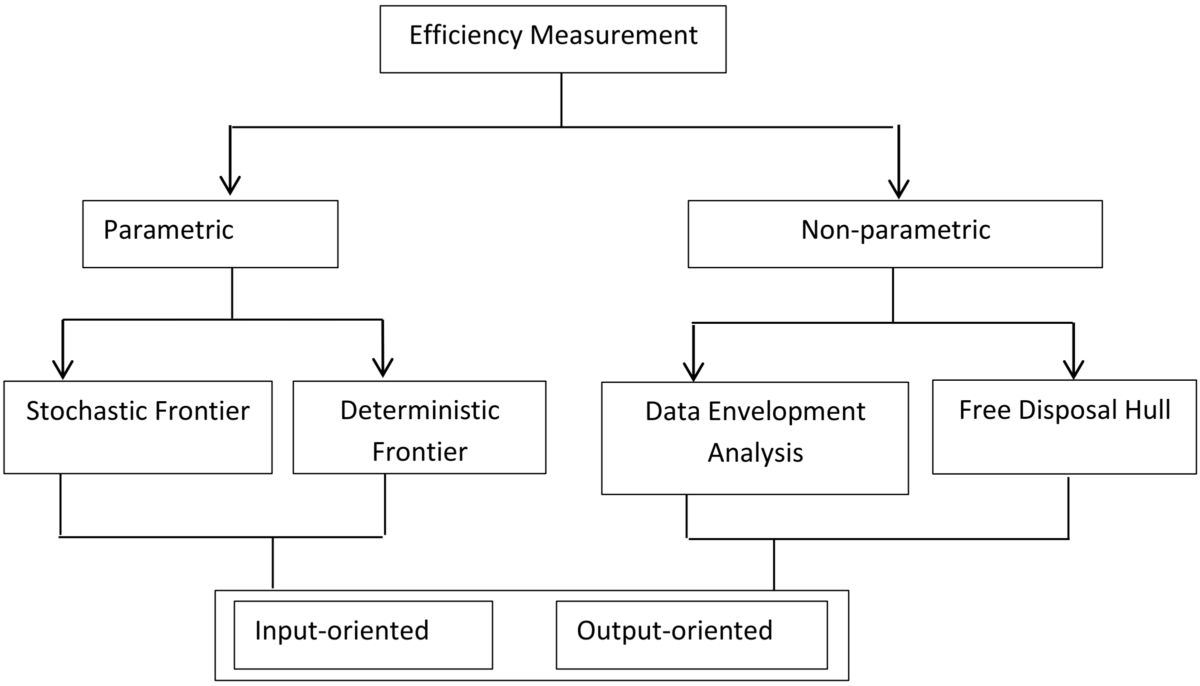

Figure 3. 2: Approaches to Efficiency Measurement

Source: Author's construction, 2020

3.6.1 Methods of Measuring or Estimating Efficiency

3.6.1.1 Parametric Models (Stochastic Frontier Approach)

Parametric approach is centred on econometric estimation of a production frontier. The approach is made up of the stochastic frontier and deterministic frontier models as earlier mentioned. By making assumptions about the data, the parametric frontier approaches impose a functional form on the production function. The commonly used functional forms consist of the functions: Cobb–Douglas, Constant Elasticity of Substitution, and translog production. The parametric approaches are divided into deterministic frontiers and stochastic frontiers. A deterministic frontier is with the assumption that all deviations from the production or cost frontier are due to the inefficiency of firms/ farmers. Conversely, stochastic frontiers assume that a portion of the discrepancies from the frontier is as a result of random noise such as measurement error and statistical noise and also partially due to firm specific inefficiency (Forsund *et al.*, 1980; Coelli *et al.*, 2005).

Stochastic frontier approach tries to differentiate effects of random noises from the effects of inefficiency. And by doing so, it has the strength of testing statistical hypothesis over the deterministic frontier. Its major shortfalls include the distributional assumption and the assumption regarding the parametric functional form for the frontier technology (Wadud, 2013). Aigner *et al* (1952), Lovell and Schmidt (1977) and Meeusen and Van Den Broeck (1977) independently postulated the stochastic frontier model. Unlike the other parametric frontier measures, the stochastic frontier approach makes space for stochastic errors arising from statistical noise. The stochastic frontier model decomposes the error term into a two-sided random error capturing the random effects outside the control of the firm (the decision-making unit) and the one-sided inefficiency component.

Critique and review of recent developments and applications of frontier techniques of efficiency measurement has been extensively dealt with by Coelli *et al*. (2005). Also, similar works on stochastic frontier functions and econometric estimation are comprehensively presented by (Forsund *et al*. (1980); Schmidt (1985); Bauer (1990); Battese (1992) and Greene (1993).

Two methodological approaches are used in analysing the sources of technical and economic efficiency based on stochastic production and cost functions respectively using the maximum likelihood techniques. The first approach involves a two-stage procedure; the first stage estimates the stochastic frontier and predicts the technical and cost efficiency for all the sampled farmers. Using Ordinary Least Squares (OLS) in second stage, the efficiency scores derived from the first stage is regressed on the farmer and farm level factors. The farmer and farm level factors are expected to be responsible for discrepancies in the farm technical, allocative and economic efficiency. It is assumed that the effects of inefficiency are identically distributed but fails to realise that technical inefficiency is a function of farmer and specific factors affecting the farmer. Results of the second stage using the OLS do not conform to the axiom of identically distributed inefficiency effects. The use of OLS in the second stage will make the prediction inconsistent with the assumption of the dependent variable (technical and economic inefficiency) being inherently one sided (Kumbhakar, 1991). Once a firm's knowledge of its level of technical or cost inefficiency determines its choice of inputs, it can be concluded that inefficiency can be dependent on the independent variables considered and hence the first approach is flawed.

The two-stage approach, using a stochastic frontier, has been applied by Kalirajan (1981) and Pitt and Lee (1981) and Heshmati and Kumbhakar (1997) for pseudo panel data, and Sharma *et al.* (1999) for cross sectional data. Timmer (1970) was one of the first to apply this approach albeit using covariance analysis in stage one. SFA involves a one-step simultaneous estimation. Thus, the parameters of the stochastic frontier and the inefficiency model are estimated simultaneously in a single-step (Battese and Coelli, 1995). The simultaneous estimation of the stochastic production frontiers and models of technical inefficiency using maximum likelihood techniques had been proposed by Kumbhakar *et al.* (1991), Reifschnieder and Stevenson (1991), Huang and Liu (1994), Battese and Coelli (1995) and Coelli *et al.* (2005). The one-stage method is proven to be statistically consistent and will result in more efficient parameter estimates (Coelli, 1996).

Review of Functional Forms of the Production Function

Functional form specification is a tradition in efficiency analysis using the parametric approach (quantitative approach). The various functional forms employed in establishing relationships between inputs and outputs in data analysis are the quadratic, transcendental (translog) and Cobb-Douglas production function (Greene, 1980a). The Cobb-Douglas and Translog production functions forms are reviewed in this study since they are the most commonly employed in economic efficiency analysis.

Cobb- Douglas Production Function

Cobb-Douglas production function is expressed in the equation below

$$InY_i = \beta_0 + \sum_{k=1}^{N} \beta_k InX_k + \varepsilon_i \qquad \textbf{[18.0]}$$

Where Y_i is the output, X_i are the input variables, β_0 and β_k are the unknowm parameters to be estimated and e_i is the error term. Cobb-Douglas production function is obtained by a linear relationship between the logarithm of output and the logarithm of the relevant inputs in production. Cobb-Douglas model was first proposed by Knut Wicksell (1851 - 1926) and was further tested by Charles Cobb and Paul Douglas against statistical evidence in 1900-1928 as cited in Shen *et al.* (2012). Like any other production model, it has since been used for a number of production analyses. It is appropriate for analyses and usually involves the estimation of fewer parameters. It assumes all firms/farmers have the constant production elasticities and that substitution elasticities are equal to one. The Cobb-Douglas production function has inherent advantages which makes it preferred for analysis. Some of its advantages include the ability to handle various econometric estimation problems such as serial correlation, multicollinearity and heteroscedasticity in a much simpler and adequate manner (Ogujiuba *et al.*, 2014). Another ability of the model is that, it facilitates computations and has the properties of explicit representability. Finally, elasticities of individual inputs estimated by this model can be easily obtained, read and interpreted and it said to be less data demanding. However, one real and obvious disadvantage with this model is the fact that, it is not a flexible functional form (Ilembo and Kuzilwa, 2014).

Translog Production Function

The translog production function is the generalized form of the Cobb-Douglas functional form and commonly used in the estimation of production analysis. In this study, it is expressed as:

$$\ln Y_i = \beta_0 + \sum_{n=1}^{N} \delta_n \ln W_{ni} + \frac{1}{2}\sum_{n=1}^{N}\sum_{n=1}^{N} \delta_{ij} \ln W_{ni} \ln W_{nj} + v_i - u_i \qquad u_i \geq 0 \qquad \textbf{[19.0]}$$

Where Y_i is the output, W_i are the input variables, $v_i - u_i$ are the error terms.

Unlike the Cobb-Douglas production function, the translog functional form is usually referred to as a flexible functional form. Just like the Cobb-Douglas functional form, the translog has inherent advantages. These include, its flexible nature, which provides lesser restrictions on production elasticities and substitution elasticities. It as well provides a second-order approximation to any underlying function. However, one setback is the fact that, this flexible functional form estimation requires a larger sample size, which is sometimes not possible. Moreover, there can be instances of multicollinearity with regards to translog model among the regressors which is likely to result in imprecise estimates of model parameters (Daghbashyan, 2011). The translog is considered as more difficult to interpret, since it requires the incorporation of more parameters than the Cobb-Douglas production function.

3.6.1.2 Non-parametric Models

There are also two methods in the application of the non-parametric approach, the Free Disposal Hull (FDH) and the Data Envelopment Analysis (DEA). The later was first initiated by Farrel in 1957 and the former developed by Deprins *et al.* (1984). The most popular and frequently used method for non-parametric model is the Data Envelopment Analysis (DEA). DEA is use in analysing, production, cost and revenue, and profit data without technology parameterization (Greene, 2008). It does not impose a functional form on the production and cost frontier while also not making any assumptions about the distribution of the error term. The DEA procedure forms a piecewise linear, quasi-convex hull around the data points in the input space (Greene, 2008). The convex hull, which is generated from a subset of the given sample, serves as an estimate of the production frontier, depicting the maximum possible output. In input orientation, this entails constructing an isoquant using the decision-making units (DMU) that are closest to the input axes. Here, DMUs refer to the respective production units. The closer a DMU is to an input axis, the less of that input the DMU is using to produce a fixed output. In output orientation, the frontier is constructed based on the DMUs that are farthest from the origin indicating that they are able to produce more from a fixed set of inputs and are, therefore, on a higher production possibility frontier.

The input orientation reveals the case of circular contraction while the output space indicates radial expansion (Chimai, 2011). Consequently, efficiency is calculated as a ratio of the real output to the maximum potential output or cost on the convex hull, which corresponds to the collection of resources and their prices. The production of the efficiency frontier in DEA stems from the concept of Pareto optimality; a firm may increase (decrease) output without necessarily increasing (decreasing) output or production of another product. Those DMUs lying on the frontier are said to be efficient and are considered as Pareto optimal units and are assigned an efficiency score of one. DMUs that are not on the efficient frontier are considered to be relatively inefficient and are assigned positive efficiency index of less than one (Chimai, 2011).

The FDH estimator has two applicable approaches. The first approach requires a mixed-integer program and the second, basic sorting routine. The firms are assigned weights in mixed-integer programming and the weights are assigned either to be zero or one that transforms the model into a mixed-integer programming problem. The simple sorting programme will require an inclusion of fixed inputs which will normally not yield variable inputs utilization rate and hence the approach is flawed. The mixed-integer programming, however, returns the optimum variable input utilization rate needed to produce at capacity which can be useful information. The FDH estimator can be determined very easily using application such as MATLAB (Matrix Laboratory) (Walden, 2010).

The non-parametric approach has suffered a number of criticisms with the major ones being the convex hull, representing the maximum possible output, is derived using only marginal data rather than all the observations in the sample. Consequently, the measures of efficiency using this approach are susceptible to outliers and measurement errors (Forsund *et al.* 1980).

3.6.1.3 Semi-Parametric Techniques

Semi-parametric is a statistical model that has parametric and nonparametric components. Is has both a finite-dimensional component and an infinite-dimensional component. Semi-parametric techniques include productivity indices, growth accounting, index theory, and many others. Semi-parametric techniques such as productivity indices, growth accounting and index theory principles can be used to measure efficiency of firms/farmers. It is worth knowing that the use of semi-parametric techniques in estimating efficiency performances of firms is not common in the literature.

3.7 Meta-Frontier Analysis

The meta-frontier methodology is used in analyzing the technical efficiency of farmers in the selected agro-ecological zones of Ghana. The meta-frontier methodology developed by Battese *et al.* (2004) is used to correct the bias caused by estimating simultaneously, the comparable efficiencies and the technological gaps for productions under different technologies relative to the potential technology available. The model produces a group or common production frontier which makes possible for the direct comparison of Technical Efficiency between different production firms (Gonzalez-Flores *et al.*, 2014). The theory of meta-frontier analysis is based on the fact that firms in different industries, regions and/or countries face different opportunities (O'Donnel *et al.*, 2008). Instead of the homogeneous assumption of production technology, resource endowments, climatic conditions made by Farrel (1957) about firms, it is possible to have the opposite assumptions. The root of meta-frontier production function is from the traditional original production frontier developed by Farrell (1957) and extended by Aigner *et al*. (1977) and Meeusen and van den Broeck (1977). Farrell (1957) developed the production frontier model that is used in the estimation of production efficiency of firms or organization with similar technology. This original production frontier model (stochastic frontier) has been modified and named "meta-frontier production function".

It is used when firms are in groups and operate under different ecological, technological or environmental conditions. The theoretical underpinning of meta-frontier production function stems from the belief that, firms located in different areas have potential access to the same or similar resources or technology through innovation diffusion model. The diffusion of technology from one firm to another or among firms creates the opportunity for firms in different locations to be able to use similar or nearly similar technologies due to the same ways of diffusion of technology. Heterogeneous firms have the potential to move up and operate on the meta-frontier which is an umbrella of group frontiers on the basis of similar or same technology level.

3.7.1 Theoretical specification of Meta-frontier Production Function

A meta-frontier production function can therefore be defined as a benchmark production function which encompasses all the group production frontiers with different technologies or environmental conditions. Therefore, in an attempt to compare the efficiency of different groups of firms, a stochastic meta-frontier production function is employed since it yields firm specific efficiency estimates which can be comparable. Incidentally, farmers' productivities are not the same in Ghana as environmental conditions and technologies as inputs for production of goods and service are different in the various ecological zones. This was buttressed by

Barnes and Revoredo Giha (2011) in their conclusion that a meta-frontier production function is suitable for studies under different technologies and environmental conditions.

Therefore, the stochastic meta-frontier production (the two-step stochastic meta-frontier model) will be used in this study since the sample consists of tomato farmers from different ecological zones.

The two-step meta-frontier, the pooling stochastic meta-frontier and the two-step mixed methods all assume that the deviations between the frontier and the observed output are caused by both factors under and beyond the control of the firm (farmer). Unlike the pooling stochastic meta-frontier model whose estimates are not exact and the two-step mixed approach also violating the standard regularity property, the new two-step approaches to estimating meta-frontier technical efficiencies are accurate and exact and meet all the standard regularity conditions (Haung *et al.* 2014). The study therefore employs the new two-step approach in estimating metafrontier technical efficiencies of tomato farmers in the three ecological zones in Ghana.

3.7.2 The New Two-Step Stochastic Meta-Frontier Models

The proposed new two-step stochastic meta-frontier by Huang et al. (2014) is the current estimation method for production efficiency analysis. Both the group specific stochastic frontier and the stochastic meta-frontier regressions are used. The group specific stochastic frontier regression is specified as:

$$y_i^k = f(x_i, \beta_i^k)\ell^{V_i^k - U_i^k} = \ell^{x\beta_i^k + V_i^k - U_i^k} \qquad \textbf{[20.0]}$$

Where y^k is group k output, x is the vector of inputs, v_i^k and u_i^k are the error terms for firms in group k, β^k is a vector of unknown parameters for group k firms.

From the above model [20.0], the group specific stochastic frontier will be first estimated and the estimated parameters and error terms pooled together for the estimation of the stochastic meta-frontier model. This is expressed as:

$$y_i^k = f(x_i, \beta_i^k)\ell^{V_i^k - U_i^k} = y^* = f(x_i, \beta_i *)\ell^{V_i^{*} - U_i^{*}} = \ell^{x_i \beta_i^* + V_i^* - U_i^*} \quad \textbf{[21.0]}$$

Where Similarly, y^k is group k output, x is the vector of inputs, v_i^k and u_i^k are the error terms for firms in group k, β^k is a vector of unknown parameters for group k firms. On the contrary, y^* is meta-frontier output and v_i^* and u_i^k are error terms for meta-frontier and β^* is the vector of meta-frontier parameters.

From equation [20] above the group technical efficiency can be derived by dividing the observed output by the frontier output. Both the frontier output and the observed outputs can be used in estimating production performance of a firm. Therefore, the technical efficiency of a group (a zone) can be expressed as:

$$TE^* = \frac{Observed\ output}{Metafrontier\ output} - \frac{y_A^1}{y^*} \quad \textbf{[22.0]}$$

For input-oriented efficiency, the technology gap ratio of farmers in eco1ogical zones can be estimated as:

$$TGR(1)\frac{Frontier\ output\ of\ farmers\ in\ the\ zones}{metafrontier\ output} - \frac{y^1}{y^*} \quad \textbf{[23.0]}$$

Finally, the meta-frontier technical efficiency *(TE*)* can be measured using the equation

$$TE^{*} = \frac{Observed\ output\ of\ agroecological\ zone}{metafrontier\ output} - \frac{y_A^1}{y^*} \qquad \textbf{[24.0]}$$

From the viewpoint of Huang *et al.* (2014), the exact nature of any estimated meta-frontier efficiency $MFTE_i^k$ justifies the definition of metafrontier as an envelope of individual frontiers. Hence, the estimated metafrontier is given as:

$$MFTE_i^k = TGR_i^k \times TE_i^k \qquad \textbf{[25.0]}$$

Where $0 \leq MFTE_i^k \leq 1, 0 \leq TE_i^k \leq 1 and 0 \leq TGR_i^k \leq 1$ while $MFTE_i^k$, are all predicted.

3.7.3 Graphical Representation of Group Frontiers and Meta-frontier

From the works of Battese *et al*. (2004) and Chen *et al*. (2014), it is tentatively assumed that there is a meta-technology set which envelopes all the group technologies in a relationship between inputs and output operating together.

Figure 3.3 below is a graphical representation of three specific frontier production functions and a meta-frontier. *G1F*, *G2F* and *G3F* show the three group frontiers while the meta-frontier is represented by *MF*. In this research, the group specific frontier denotes the technology used to transform inputs into output in a particular agro-ecological zone on the basis that similar economic resource, technologies and environmental conditions pertain to all the zones.

The technical relationship of the input, x and the output, y is the meta-technology *(MT)* while each of the group production frontiers *(G1F, G2F and G3F)* represents the relationship that transforms the input x into output y in tomatoes production process. The group production frontier is the boundary of output set for each group.

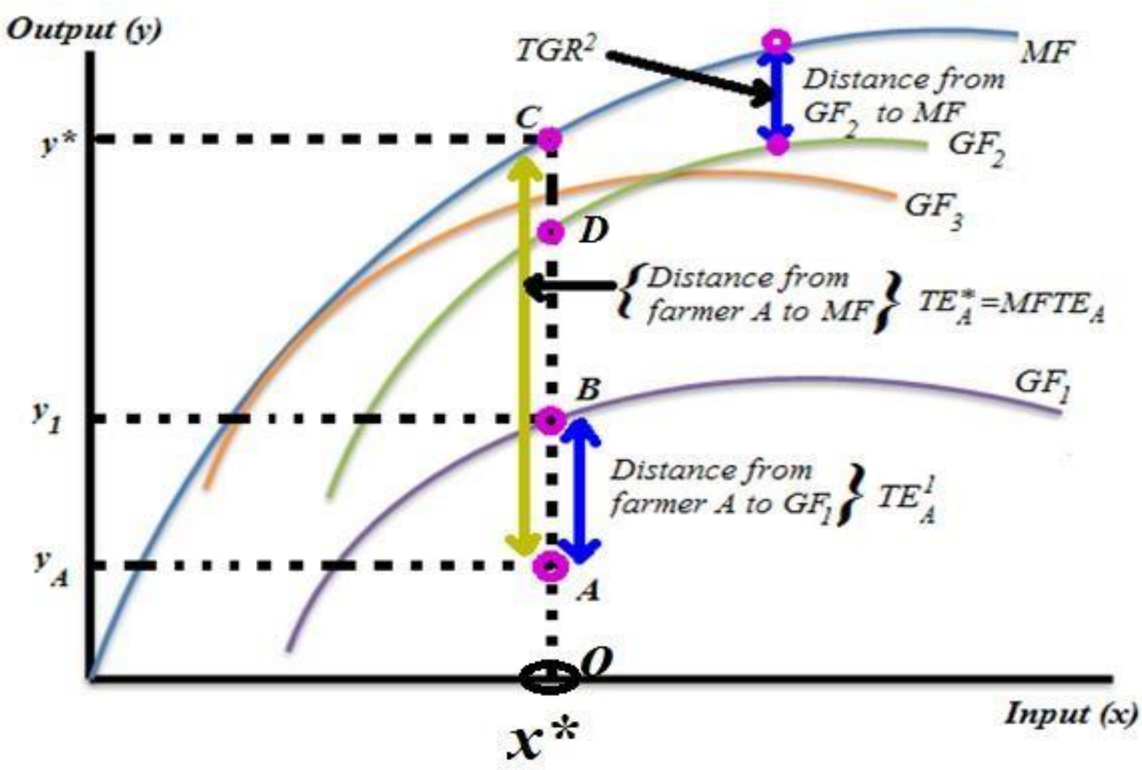

Figure 3.3: Graphical Representation of Meta-frontier

Source: Adopted from Battese et al. (2004) and Chen et al. (2014)

If a farmer operates at point A, (i.e., the farmer uses x^* quantity of input x to produce y_A quantity of output y), the technical efficiency relative to meta-frontier (individual frontier) can be measured. The theoretical underpinning of efficiency estimations in this study is grounded in production theory, implies the output meta-distance is the vertical distance between the horizontal axis and the meta-frontier production. The output meta-distance therefore provides the basis for measuring efficiency of the specific group. From the graph the technical efficiency for group one is measured as the distance between *GF1* and *MF*. Given that farmer A is at point A, the technical efficiency *(TE)* of that farmer relative to group one frontier (GSZ) using x^* quantity of input is given as:

$$TE_A^1 = \frac{OA}{OB} = \frac{y_A}{y_1} \qquad \textbf{[26.0]}$$

The higher the technical efficiency index (TE_A^1), the more innovative is the farmer (A) and the less technical efficiency index (TE_A^1) the less innovative is the farmer (A). It is possible to measure group specific technical efficiency relative to the meta-frontier production function and this estimate is called meta-technology ratio *(MTR).* The meta-technology ratio (*MTR)* is the ratio of the technical efficiency relative to the metafrontier (TE^*) to the technical efficiency relative to the group frontier (TE^k). According to Boshrabadi et al. (2008), meta-technology ratio can also be referred to as environmental technology gap ratio *(ETGR)* or technology gap ratio *(TGR),* because it accurately describes the inability of a farmer in a particular agro ecological zone to achieve potential output due to environmental and technological differences.

TGR may be expressed using (x^*) quantity of inputs relative to farmers operating on group one frontier as:

$$TGR = \frac{TE_1^*}{TE_A^1} = \frac{OA/OC}{OA/OB} = \frac{y_A/y^*}{y_A/y_1} = \frac{OB}{OC} = \frac{GFoutput}{MFoutput} = \frac{y_1}{y^*} \qquad \textbf{[27.0]}$$

Assuming a farmer at point A could use the joint technology, the meta-frontier technical efficiency $(MFTE)$ score or the technical efficiency relative to the meta-frontier (TE_1^*) can be determined by using the index:

$$TE_1^* = MFTE = MTR^1 \times TE_A^1 = \frac{OB}{OC} \times \frac{OA}{OB} = \frac{OA}{OC} = \frac{y_A}{y^*}$$

[28.0]

From equation [28], the technical efficiency relative to the meta-frontier TE_1^* is the sum of the technical efficiency relative to the group and the environmental-technology gap ratio (MTR) between the meta-technology and the technology gap ratio.

3.7.4 Properties of Productivity Performance Indices (TE, MFTE, TGR*)*

The Group specific technical efficiency, meta-frontier technical efficiency (MFTE^k) and the technology gap ratio fall within the ranges $0 \leq TE^k \leq 1; 0 \leq MFTE^k \leq 1$ and $0 \leq TGR^k \leq 1$. A firm/farmer who is able to obtain a unit value for each of these efficiency indices is classified as 100% efficient in his or her production activities. However, in the real-life situation, it is impractical or impossible for a firm/farmer to obtain 100% efficiency in production of goods and services. Therefore, the closer the productivity performance index to unity (100%), the more efficient the firm/ farmer.

On the other hand, it is possible to have zero efficiency. With this outcome a firm/farmer can obtain zero productivity performance indexes: that is $TE^k = 0, MFTE^k = 0 \, and \, TGR^k = 0$. Again, it is worth knowing that, $MFTE^k > TE^k$ and at a point where group specific frontier "k" intersects the meta-frontier, the group specific frontier output and meta-frontier output will be equal. With such a situation, TGR^k will be equal to one, implying that firms/farmers in k^{th} group have 100%

potential of producing the maximum output regardless of the heterogeneity of technologies or environmental conditions. However, this is not possible in real life situations.

3.8 Stochastic Frontier Model with Sample Selection

In many fields, especially agricultural economics, Stochastic Production Frontier (SPF) models have been widely used to model input-output relationships and to measure the TE of farmers (Bravo-Ureta et al., 2007). It has also been used to compare farmers' output under various technological interventions. For example, the method has been used to examine the impact of technology adoption on output and technical efficiency (TE) of rice farm (Villano et al., 2015)

Most studies that have used SFAs to compare the TE of adopters against non-adopters were found to be constrained in their ability to account for selectivity bias resulting from both observable and unobservable variables in a way that is compatible with the nonlinear nature of the SFM. As cited by Villano et al. (2015), failure to account for selectivity bias leads to inconsistent and biased estimates of TE. For instance, following Heckman's (1979) methodology to account for selection bias, several attempts have been made to address sample selection in a stochastic frontier framework. Sipilainen and Oude Lansink (2005) added an inverse Mill's ratio (IMR) to the deterministic part of the frontier function to examine possible sample selection bias in the analysis of organic and conventional farms. However, this procedure has proven unsuitable for nonlinear models such as the SPF (Greene, 2010).

Also, Issahaku and Abdulai (2020) and Villano et al. (2015) employed the sample selection approach proposed by Greene (2010) to estimate the effect of adoption of rice and sustainable agricultural practices on farmers' TE. The proposed model by Greene (2010) assumes that the unobserved characteristics in the selection equation (decision variable) are correlated with the conventional error term in the stochastic frontier model. This approach assumes that, the group TE estimates alone do not allow for accurate comparison of the productivity between adopters and non-adopters, as this approach does not account for technology differences (O'Donnell, Rao, and Battese, 2008). The adoption of an improved technology could result in heterogeneous production technologies undertaken by smallholder farmers (Khanal et al., 2018; O'Donnell, Rao, and Battese, 2008). Such technology differences will require a metafrontier and group-specific frontiers. To correct for observed biases, the PSM is employed to match the characteristics of adopters to that of the non-adopters. The standard probit/logit model is employed to generate "propensity scores" (Issahaku, and Abdulai, (2020), Villano et al. (2015)). These scores are based on the fact that both treated and non-treated (control) groups possess the same characteristics. The selectivity bias correction SPF model accounts for biases due to unobserved factors in both the selection model and the outcome model.

Unlike studies conducted by Villano et al. (2015) and Issahaku and Abdulai (2020) where the decision variable is binary, in this study, the decision variable (ITSV) has more than two categories. This makes it impractical for this study to use the Greene (2010) approach. The study therefore employed the Metafrontier technical efficiency based on technology difference to generate the MTE scores, then used the PSM to match treated group (adopters) against the non-treated group (Non-adopters) who possess the same characteristics for the individual seed varieties.

THE CONCEPT OF MARKETING AND MARKETING EFFICIENCY MEASUREMENT

3.9 Theoretical Review of Marketing

Marketing can be explained as encompassing all activities concerned with moving and selling goods (Balogun et al., 2018). Agricultural marketing, in particular, refers to the performance of all business activities (marketing functions) involved in the flow of goods and services from the point of initial agricultural production to the ultimate consumers (Kohls and Uhl, 1990). These activities include packaging, storage, transportation, pricing, financing, risk bearing, and product design (Balogun *et al.*, 2018).

In the broadest sense, marketing could be referred to as a set of processes for creating, communicating and delivering value to customers and for managing customer relationships in ways that benefit the organization and its stakeholders (American Marketing Association (AMA, 2004). Thus, marketing goes beyond just promotion and personal selling to include education (Kerin *et al.*, 2013).

Marketing could also be explained using various characteristics such as system and scope. There are two forms of marketing systems: formal and informal (Mbogoh, 1993). Sellers in formal markets operate publicly by advertising their products, prices and locations (Anbarci *et al.*, 2012). In formal markets, sellers are taxed. However, in informal markets, sellers operate through bilateral bargaining and anonymously (Anbarci *et al.*, 2012).

In marketing, actors look for markets to source their goods from and buyers to sell their goods to (Abbott, 1993). In the process and before selling the product to the consumers, actors may undertake several of the above marketing operations to keep the product in good shape and increase the value of the product (Asogwa and Okwoche, 2012). If the marketing activities are enhanced to provide better produce to customers, marketers tend to earn more income (Ukwuaba, 2017).

3.9.1 Agricultural Commodity Marketing

Agricultural marketing plays a pivotal role in enhancing production and consumption and thereby accelerates the pace of economic development (Khols and Uhl, 1998). Increased efficiency in agricultural marketing could spur industrialization and increase farm incomet throug reduction in cost of distribution and pricing to consumers and result in an increase in the national income. Khols and Uhl (1998) again indicated that a marketing system that is efficient may contribute to increasing the marketable surplus by scaling down the losses arising out of the inefficient processing, storage, and transportation. Farmers are assured of better prices for their products and induce them to invest their surpluses in the purchase of modern inputs so that productivity may increase.

3.9.2 Tomato Marketing Channels and Value Chain Actors

The prevailing tomato value chain is made up of farmers, market traders (wholesalers and retailers), and buyers. The tomato value chain can simply be viewed as the routes through which tomato pass to reach final consumers. In Ghana, huge tomato markets are often located in the cities whereas production is a rural activity - generally done in a village or small town -by small-scale farmers. Wholesalers (market queens) buy and sell large quantities of tomatoes, usually in big and terminal markets while retailers buy and sell small quantities of tomatoes directly to final consumers. Market queens exercise greater power in the market. Relatively, the retailers are many which make their business highly competitive. The study identified four types of marketing channels and relationships in the Ghanaian tomato value:

(1) Producers → Wholesalers (Market Queens) → Retailers → Final Consumers
(2) Producers → Wholesalers (Market Queens) → Final Consumers
(3) Producers→ Retailers → Final Consumers
(4) Producers → Final Consumers

Off-taking of tomato occurs when farmers begin to harvest the crop. Transaction activities in both producer and consumer markets occur everyday. For tomato, harvesting can be done continuously for 3-6 months if the farm is properly managed. The channel through which tomato passes to reach the final consumer can be long or short. In the first route, the harvested tomato passes through many hands before it gets to the final consumer. In the second route, wholesalers can sell the harvested produce directly to consumers after they have bought the products from the farmers. Similarly, retailers can sell the harvested produce directly to consumers once they take possession of the produce from the farmers. In the fourth and final route, producers can also sell the harvested produce directly to the final consumers without passing through the hands of market intermediaries.

3.9.3 Marketing Margin

The widely used indicator of a marketing system's performance is the marketing margin often called price spread (Abbott and Makeham, 1990). It is used to show how expenditure of consumers is split among market participants at different levels of marketing systems. Marketing margin is defined as the difference between the price paid by customer and the price received by producers or the price of a set of marketing services which is the outcome of the demand for and supply of such services. Several marketing studies (e.g., Wohlengenant and Mullen, 1987; Schroeter and Azzam, 1991; Holt, 1993) examined the marketing margins for various commodity types to investigate the performance of agricultural products.

Sexton *et al.* (2005) in their analysis of factors that influence marketing margins of firms stated that marketing margins vary due to differences in marketing costs and other factors such as seasonality, innovation and sales volume. Some authors (e.g., Brorsen *et al.*, 1985; Wohlengenant and Mullen, 1987; Schroeter and Azzam, 1991) used the observed margin as a dependent variable in estimating the variations in the margins while others (e.g., Holt, 1993) used the expected margin as a dependent variable and considered both the variance and the mean of the output price. Holt (1993) criticized the former for not taking expectations with regards to both the mean and variance of the output price.

3.9.4 Market Power

Market power expresses the extent to which a firm has discretion over the price that it charges (White, 2012). Market power refers to the ability to increase prices without losing potential customers to competitors. Unlike other markets, marketing actors in perfectly competitive market have no market power. Access to market power offer firms the ability to affect either the total quantity or the existing price in the market or both. Perfect competitive market is used as a benchmark in estimating the extent of firm's market power in buying or selling a commodity. In a perfect competitive market, each firm in the market has price being equal to marginal cost. Most studies in attempt to estimate the extent of market power, measured the gap between the price and the marginal cost (White, 2012). Firms with market power are able to charge consumer prices above marginal cost. Oligopoly or oligopsony power, when exercised by intermediaries, is harmful to producers because both forms of market power reduce sales of the farm commodity through the intermediate channels (Sexton and Zhang, 2001). Market prices are set above the competitive level when there exists oligopoly power at retail/wholesale markets, which may reduce sales and shift the product to alternate market outlets. Oligopsony power in procurement reduces prices to producers below the level that would prevail under perfect competition.

Evidence of market structures on food industry suggests markets dealing in food product are not in perfect competition (Connor *et al.*, 1985; Sexton and Zhang, 2001). Sexton *et al.* (2005) stated that the imperfection in perishable commodities is more visible and gives intermediaries the opportunity to exploit the inelastic nature of short-run supply to mark-up prices in excess of marginal cost. Prior to the early 1900, imperfect competition in the marketing of perishable commodities was analyzed based on the traditional elastic supply assumptions and on the price linkages among marketing actors and across regions with no structural models for price determination. However, structural model of short-run price determination which accounted for the inelastic nature of short-run supply of perishable commodity marketing was provided in the seminal work of Sexton and Zhang in 1996 (Iddi et al, 2017). Sexton and Zhang (1996) modeled farm price determination in a switching regression framework in which price is determined based on the harvest price or at the cost above the harvest price based on the relative bargaining power of buyers and sellers.

3.9.5 Output Price Risk

Firms usually make commodity purchase decisions without knowing the future selling price in marketing of commodities. This means that, in trade, output price risk is borne by firms while economic theory predicts compensation for it. Holt (1993) empirically analyzed the impact of output price risk on the marketing margin of agricultural products by using a variant of Sandmo's model of the firm under output uncertainty. A study conducted by Brorsen *et al.* (1985) showed marketing margins are affected by output price risk. The Sandmo model has been extended by Schroeter and Azzam (1991) to capture the non-competitive behavior of the marketing firms though they failed to estimate the generalized autoregressive conditional heteroscedasticity (GARCH) process simultaneously with their model of structural equations. This leaves the process of generating the output price variability exogenous (Holt, 1993). Many marketing studies have assigned a marketing margin above the marketing costs as a reward for buyers' risk bearing by consumers (Haung *et al.*, 2006). In several of these studies (e.g., Brorsen *et al.*, 1985) and the GARCH (e.g., Schroeter and Azzam, 1991; Holt, 1993; Haung *et al.* 2006), econometric techniques such as the fixed-weight moving averages were used to estimate the impact on market risk.

A study by Haung *et al.* (2006) argued that the omission of one of the variables from the model may result in an omitted variable bias, thereby ignoring both the effect of market power and the output price risk in the calculation of farm prices.

3.9.6 Marketing Efficiency

Theoretically, efficiency along the marketing chain is determined by cost analysis, which highlights the main marketing functions and its corresponding costs facing the actors along the marketing chain.

Okereke (1988) stated that marketing efficiency consists of price efficiency, operational efficiency and innovation efficiency. However, in this study, the concept of marketing efficiency refers to only price efficiency and shows the effectiveness of the movement of tomatoes between the originating source and the destination of tomato markets. While there are many approaches for computing market efficiency, the marketing margin is used in this study. In an efficient marketing system, all the actors' marketing margins are supposed to be equal to the correlated inter-market prices indicating an integrated marketing system.

3.10 Conceptual Framework of the study

The conceptual framework for the study is presented in Fig 3.4. Smyth (2004) defined a conceptual framework as a deep thinking or conceptualization of the processes or linkages or systems that can be used to simplify the understanding of a particular study. A conceptual framework tries to explain the linkages that exist among various concepts or variables used in the study. It starts from an inductive viewpoint to a deductive or from a simple to complex model below

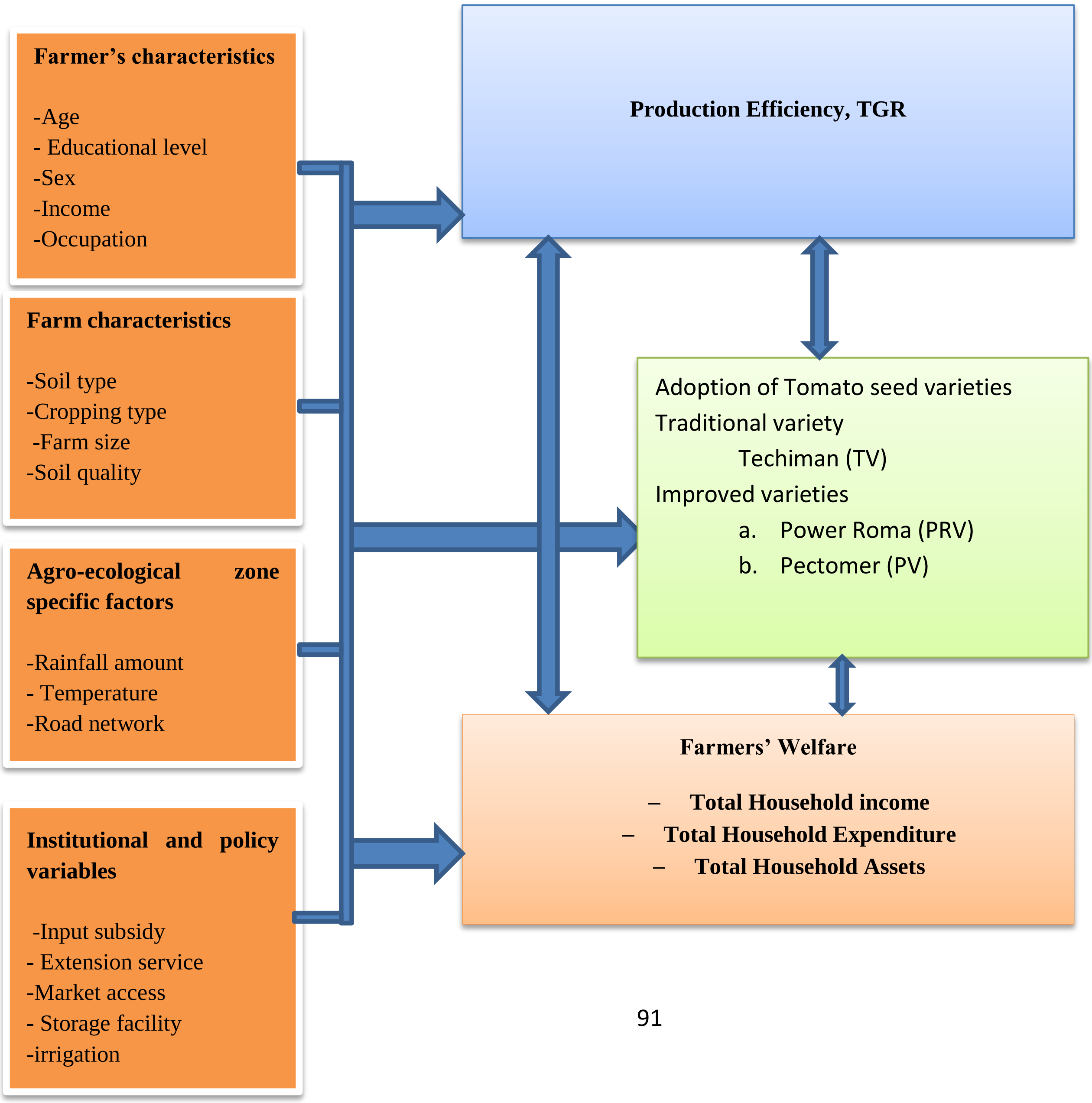

Figure 3.4 Conceptual Framework of the Study

Source*: Modified from Kiatpathomchai (2008) and Alemaw (2014).*

The conceptual framework shown in Figure 3.4 is adapted from the works of Kiatpathomchai (2008) and Alemaw (2014). Alemaw (2014) showed how farmer specific characteristics, institutional and policy factors and psychological factors affect the adoption of a new maize technology (improved maize variety). Also, the conceptual framework designed and used by Kiatpathomchai (2008) examined the effects of farm household characteristics and rice farming practices on efficiency. This study combined the conceptual framework of Kiatpathomchai (2008) and Alemaw (2014) and added agro-ecological zone-specific characteristics which were termed as environmental factors by Shiferaw *et al.* (2014) in order to take care of heterogeneity owing to the adoption of different ITSV by the various agro-ecological zones. The study also added relationship between production efficiency and welfare.

Three main tomato seed varieties were predetermined for the study, namely; Techiman (TMSV), Power Roma (PRV) and Pectomer (PV). While TMSV is the traditional variety, Power Roma (PRSV) and Pectomer (PSV) are the modern varieties. Literature on adoption (e.g., Feder, Just, & Zilberman, 1985; Kassie, Jaleta, Shiferaw, Mmbando, & Mekuria, 2013; Kassie, Teklewold, & Jaleta, 2015; Makate, Makate, & Mango, 2017; Manda, Alene, Gardebroek, Kassie, & Tembo, 2016) often argue that farmers' decisions regarding farm technologies are influenced by socio-demographics and economic characteristics. The current study follows the same line of argument that farmers' adoption of ITSV will depend on socio-demographics and economic characteristics including age, sex, occupation, household size, education, income, among others. Beyond the socio-demographic and economic characteristics, a farmer's decision to adopt a particular ITSV could also be influenced by farm-specific factors, institutional, policy variables of the country and the agro-ecological/location factors (Binswanger & Rosenzweig, 1986; Binswanger & Pingali, 1988; Erenstein, 2006). In this study, these factors are captured using farm size, soil type, cropping system, irrigation, input subsidy, extension service, market access, rainfall and temperature, among others. The relationship between these variables and adoption is shown in Figure 3.4 above.

The adoption of ITSV is believed to lead to an increased or a decrease in production efficiency and welfare (Abdallah, Abdul-Rahaman, & Issahaku, 2021; Asante, 2014; Solís, Bravo-Ureta, & Quiroga, 2009). But technical efficiency and welfare are also influenced by the socioeconomic factors (farm, farmer-specific, agro-ecological and institutional factors. Technical efficiency measured here is in the form of individual farm firms' technical efficiency with respect to similar farm firms in the same agro-ecological zone as well as to the overall efficiency levels across all the zones. Impact of adoption ITSV is operationalized as mean technical efficiency in the case of impact on efficiency and welfare operationalised as total household income, total household expenditure and total fixed assets. Total household income, total household expenditure and total fixed assets were choosen as proxy variables for welfare following the works (see H. Liet al., 2015; Mathengeet al., 2014; Michelson, 2013; Wossen 2017). Welfare is operationalized as the wellbeing of farmers, taken into consideration the farmers infrastructure, social status and the available social amanities at the farmers' services (GSS, 2014). Again the conceptual framework shows relationship between production efficiency and farmers' welfare, where the production efficiency of a tomato farmer could have either a positive or a negative impact on the farmers' wellbeing.

Foster and Rosenzweig (2010) indicated that a farmer's decision to cultivate tomatoes is based on the notion of profit maximization, given farm specific characteristics (such as inputs availability, soil quality, size of land, cropping system, soil type and others). Farmers are rational economic agents who aim at maximizing utility (profit) by adopting a particular ITSV. The choice of tomato seed adopted is a key determinant of changes in prices of agricultural products (Kijima *et al*, 2011). Hence, a farmer's level of utility maximization depends on his/her ability to make the best alternative choice(s) among available tomato varieties.

3.10.1 Theoretical Frameworks for Adoption

Theory of Random Utility

This study is based on the random utility theory, which is founded on utility maximization. It is adopted to explain farmers' adoption of ITSV. Maximization of utility is the best developed formal theory of rationality which constitutes the core of neoclassical economics (Zey, 2015). The decision to adopt in agriculture helps farmers and consumers to estimate their profit maximization or utility maximization. A farmer producing tomatoes has an option of being a net adopter of some improved variety of seeds. This involves making decisions on the assumption that, ranks can be made for the utility a farmer derives from adopting a particular seed variety.

The rational choice theory suggests that when an individual or economic agent is faced with a number of choices, he/she will prefer a choice that maximizes his/her expected utility[ii] of wealth. By so doing, the theory assumes that rational behavior governs decisions of an individual or economic agent. Thus in accordance with the theory, an individual or economic agent i will choose any package j over any alternative package m if $U_{ij}(\pi) > U_{im}(\pi)$ or $\Delta U_{im} = U_{ij}(\pi) - U_{im}(\pi) > 0$ and $m \neq j$

in all cases. This is under the assumption that the individual or economic agents are risk neutral and take into account the net benefit derived from such practice during the decision-making process. However, the benefit or utility of wealth $U^*_{ij}(\pi)$ derived from choosing package j is a latent variable and as a researcher one cannot directly observe the parameters of such package. The econometric inference problem then becomes a question of parameterizing the equation that defines the net utility of wealth. According to Green (2002), although the preferences of the individual or the agent are not known to the researcher, his/her characteristics and as well as the attributes of the program (adoption of ITSV in the case of this study), X are observed during the survey. Green (2002) further pointed out that such characteristics (X) can be used to determine the choice of the individual in the following fashion:

$$U^*_{ij} = \delta_j \mathrm{X}_\mathrm{i} + \varepsilon_{ij} \qquad \textbf{[29.0]}$$

Assuming $ITSV$ is the index variable for each of the unobserved preferences, equation (29.0) translates into the observed binary outcome equation for each choice as follows:

$$TV = \begin{cases} 1 & if \quad U^*_{i1}(\pi) > \max\limits_{m \neq j}[U^*_{im}(\pi)] \ \ or \ \ \eta_{i1} < 0 \\ :: & :: \quad :: \qquad\qquad\qquad\qquad \text{for all } m \neq j \\ J & if \quad U^*_{ij}(\pi) > \max\limits_{m \neq j}[U^*_{im}(\pi)] \ \ or \ \ \eta_{ij} < 0 \end{cases} \qquad \textbf{[30.0]}$$

Where $\eta_{ij} = \max\limits_{m \neq j}[U^*_{im}(\pi) - U^*_{ij}(\pi)] < 0$ in (30.0) as indicated by Bourguignon et al. (2007); further, equation (30.0) implies that the decision maker will choose package j to maximize his/her expected utility of wealth if package j provides greater expected utility of wealth than any other package $m \neq j$, that is if $\eta_{ij} = \max\limits_{m \neq j}[U^*_{ij}(\pi) - U^*_{im}(\pi)] > 0$. Giving that ε in equation (30.0) is identically and independently Gumbel distributed, McFadden (1973) argued that the probability that the decision maker will choose package j can be specified by a multinomial Logit model which is discussed in the subsequent section.

The decision of a farmer to adopt an ITSV depends on socio-demographics and economic characteristics including age, sex, occupation, household size, education, income, among others. Beyond these factors a farmer's decision to adopt a particular ITSV could also be influenced by some other factors, such as farm-specific factors, institutional, policy variables of the country and the agro-ecological/location factor (Erenstein, 2006).

3.10.2 Theory of Agricultural Households

In order to illustrate and compare the links between adoption (ITSV) and household welfare indicators, this study adopts the agricultural household model modified by Fernandez-Cornejo et al. (2005) to incorporate technology or innovation in the farm household model. Basically, the model captures the farm household's consumption and production interdependences in a theoretically coherent manner. As a starting point, the model assumes that the objective of farm households is maximization of expected utility which is subject to production technology, budget and other resources such as time constraints. These are specified as:

$$U = U(G, L, H) \quad \textbf{[31.0a]}$$

Subject to constraints:

$$Q = Q[X(g), F(g), H, g, R \quad \textbf{[31.0b]}$$

$$P_g G = P_q Q - P_x, X - wN + E \quad \textbf{[31.0c]}$$

$$T = F(g) + L + N \quad \textbf{[31.0d]}$$

where G represent goods purchased by the household for consumption, L is leisure and H is a non-choice vector of variables, representing individual, household and community characteristics, such as ages, years of education, household size and other environmental variables as indicated in equation (31.0a). For the production technology in equation (31.0b), Q is the household's production of staple food, X captures input use (e.g., land, seeds, fertilizer, chemicals etc.) which is also a function of the adoption of ITSV; T is the total time available to the household and consist of L which is as defined earlier; F and N are the respective times allocated to farm work and off-farm; H is as defined above; and R is a vector of exogenous factors that shift the production function. Also, P_g, P_q, w, and P_x are the prices of purchased goods, output, off-farm wages and variable inputs respectively; and E is other income, including income from interest, dividends, annuities, private pensions, and rents and government transfers (such as social security, retirement, disability, and unemployment). Following Fernandez-Cornejo et al. (2005) and substituting the production technology function (32a) into the budget equation (32b) yields:

$$P_g G = P_q Q[X(g), F(g), H, g, R] - P_x X - wN + E \qquad \textbf{[31.0e]}$$

the first-order conditions for optimality (Kuhn-Tucker conditions) are obtained by maximizing the lagrangian expression (U) over (G, L, H)

$$\begin{aligned} &+ \lambda P_q Q[X(g), F(g), HgR] - P_x X - wN + E - P_g G + \\ &u[T = F(g) + L + N] \end{aligned} \qquad \textbf{[31.0f]}$$

Note: The adoption decision may be obtained following Kuhn-Tucker conditions.

EMPIRICAL REVIEW

3.11 Empirical Review on Determinants of Adoption of Agricultural Technologies

Adoption or adaption of new agricultural technologies is a decision which is determined by certain factors. Alemaw (2014) indicated that households' personal and demographic variables are some of the factors that affect their adoption behaviour. These factors can be grouped into farmer characteristics, environmental factors and institutional and policy factors. Under farmer specific characteristics, researchers such as Nchinda et al. (2010), Asfaw and Shiferaw (2010) and Donkoh et al. (2016) have modelled age, sex, household size, farming experience and education as the determinants of agricultural technology adoption. Agricultural extension contacts, credit access or amount, contract farming, access to input subsidy and membership of farmer-based organizations are some of the institutional and policy variables that have been extensively modeled as factors influencing the adoption of agricultural innovations or technologies (Diagne and Demont, 2007; Mekonnen, 2007; Donkoh *et al.*, 2016 and Azumah *et al.*, 2016).

Legesse *et al*. (2001) demonstrated that distance to market is a determining factor of adoption and intensity of use of technologies. The environmental conditions such as rainfall, temperature, wind and topography of the farm land have been used as factors influencing technology adoption. Shiferaw *et al*. (2014) included an environmental factor such as moist mid highlands as a determinant of adoption of improved wheat variety and realised that it was statistically significant.

3.11.1 Empirical Studies on the Impact of Adoption

Most empirical studies have shown that improved agricultural technology or innovations have contributed significantly to increased production and farm-level efficiencies, improved incomes and overall wellbeing of the farm households.

A research by Danso-Abbeam et al. (2018) on the effect of agricultural extension programmes on farm productivity and income of farmers in Northern Ghana using Heckman treatment effects model, regression on covariates, and regression on propensity scores showed a positive and statistically significant effect of extension programmes delivered by ACDEP on farm productivity and incomes.

A study conducted by Baiyegunhi et al. (2018) using PSM on the impact of outsourced extension programme on farmers' net farm income indicated a positive and significant farm income gain from the programme.

Wosen et al. (2017) studied on the impact of cooperative membership on farm technology adoption and welfare using propensity score techniques, specifically Inverse-probability-weighted Regression (IPWRA). Their findings indicated that being a member of cooperative society had a positive and significant impact on adoption of farm technology and household welfare (proxy as consumption per capita).

A multinomial endogenous switching regression model was also used by Mutenje *et al.* (2016) to determine the effect of innovations on crop yield and food security in Malawi. The study revealed that joint adoption of enhanced storage facilities and improved maize varieties significantly contributed to maize yield in Malawi, compared to other technology combination.

A study conducted by Kankwamba and Mangisoni (2015) on the effect of the adopting SAPs on maize output and household incomes of smallholder farmers in Malawi also used multinomial endogenous switching regression model. Their result suggested that the adoption of SAPs such as improved seed and soil and improved water conservation increased output and household income.

Shiferaw et al. (2014) used endogenous regression complemented with propensity score matching to analyze the impact of improved wheat variety on farmers' food security status in Ethiopia. The two econometric techniques produced consistent results suggesting that the use of improved variety of wheat improves the food security status of the farm households. That is, adopters were found to be better off because of adoption and the non-adopters would have been more food secure had they adopted.

Di Falco (2014) in his studies on the effect of multiple interdependent climate change adaptation strategies on net income per hectare of farm household in SSA used multinomial endogenous switching regression. His study showed that the highest net revenue was earned by farmers who integrated soil and water conservation strategies and modified crop varieties to reduce the impact of climate change on agricultural production.

Kassie *et al.* (2014) used multinomial endogenous switching regression model to assess the simultaneous adoption of both crop diversification and maize–legume intercropping. The findings revealed intercropping and rotations and minimal tillage ensured greater food security and larger reduction in Malawi's downside risk.

A research by Teklewold *et al.* (2013) on the effect of the adoption of multiple sustainable agricultural practices (SAPs) by farmers on household maize income, agrochemical usage and demand for family labor in rural Ethiopia using a multinomial endogenous switching regression model, used decision variables such as: maize-legume cropping system diversification, conservation tillage and modern seed adoption. The factors affecting the adoption of the SAPs were: soil characteristics and plot distance from home; rainfall and plot level disturbances; social capital in the form of access and participation in rural institutions; the number of families and traders known to the farmer; market access; wealth; age; spousal education; family size; the farmer's expectations of government help in the event of crop failure; and confidence in the skills of public extension agents. The study further revealed that household maize income was higher for farmers with a combined adoption of SAPs than farmers who adopted any one of the SAPs. Also, the results showed that conservation tillage and cropping system diversification had negative impact on nitrogen fertilizer use but conservation tillage increased pesticide application and household labour demand among maize farmers in Ethiopia.

3.11. 2 Empirical Review of the impact of adoption on Technical efficiency

Ronald (2020) investigated the determinants of cassava farmers' technical efficiency and the impact of Rural and Community Bank (RCB) credit access on farmer's technical efficiency in the Eastern Region of Ghana using SF and the endogenous switching regression model. Their findings showed half of smallholder cassava farmers in the district were aware of RCB credit facilities. Although the cassava farmers exhibited increasing returns-to-scale, they were technically inefficient operating 28.1 per cent away from the frontier. Gender, extension access, membership in farmer-based groups, reduced farmers' technical inefficiency. The first stage of the endogenous switching regression revealed that gender, extension access, land ownership and off-farm income positively influenced farmers' decision to access

RCB credit. Overall, RCB credit access had a positive and significant impact on farmers' technical efficiency among those who accessed it.

Issahaku (2019) examined the drivers of sustainable land management practices on farm households' technical efficiency using a matching technique and selectivity biased-corrected stochastic production frontier to account for bias from both observed and unobserved factors. The findings revealed that the group of farmers who adopted SLM technology exhibited higher levels of technical efficiency as compared to non-adopters.

Geffersa et al. (2019) examined the effect of technology adoption on technical efficiency (TE) in the Ethiopian maize sector using a comprehensive household-level data collected in 2011 from five major maize-producing regions in Ethiopia using propensity score-matching technique. The study estimated TE while accounting for the potential technological difference between improved and local maize varieties and addressing self-selection bias resulting from farmers' decisions to adopt new crop varieties. Their results confirmed that imposing a homogenous technology assumption for improved and local maize varieties biases efficiency estimates and the ranking of farmers based on their efficiency scores. The mean TE of 66.18%, estimated after correcting for technology difference and self-selection bias, indicated that an increase of around 33.82% in maize productivity could be achievable with the current input levels and technology.

A study by (Obayelu et al. 2016) on the perceived effects of adoption of selected improved food crop technologies (maize) by smallholder farmers along the value chain in Nigeria, using endogenous switching regression revealed very low technology adoption index. They found crop types, farm size and locations as the main determinants of adoption. Their findings also revealed maize adoption to have impact on farmers' total output.

Using propensity score matching to mitigate the effect of biases from observable variables, Villano et al. (2015) used cross-sectional farm-level data from 3,164 rice-farming households in the Philippines, to examine the impact of modern rice technologies on farm productivity while disentangling technology gaps (the distance between production frontiers) from managerial gaps (differences in technical efficiency). The study combined a recently developed stochastic production frontier framework with impact evaluation techniques to control for biases stemming from observables and unobservable. Their results showed that the adoption of certified seeds has a significant and positive impact on productivity, efficiency and net income in rice farming.

3.12 Empirical Review of Multinomial Endogenous Switching Regression Model

The effect of adopting two or more technologies is mostly estimated with multinomial endogenous switching regression. Teklewold *et al.* (2013) used multinomial endogenous switching regression model in determining the impact of farmers' adopting multiple sustainable agricultural practices (SAPs) on household maize income, agrochemical use and family labor demand in rural Ethiopia

A multinomial endogenous regression model was used by Di Falco (2014) in his research to determine the impact of multiple interdependent climate change adaptation strategies on net revenue per hectare of farm households in Sub-Saharan Africa.

Again, Kassie et al. (2014) applied multinomial endogenous switching regression model on the determinants of simultaneous adoption of crop diversification (maize–

legume intercropping and rotations) and minimum tillage. The study found that adoption resulted in greater food security and larger reduction in downside risk in Malawi.

Furthermore, a multinomial endogenous switching regression was used by Kankwamba and Mangisoni (2015) in estimating the impact of sustainable agricultural practices on maize output and household incomes of smallholder farmers in Malawi.

Also, Mutenje *et al.* (2016) used multinomial endogenous switching regression model to find impacts of innovations on crop yield and food security in Malawi.

3.13 Empirical Studies on Determinants of Technical Efficiency

Several factors have been suggested to affect efficiency of farmers. These factors include socio-economic and demographic factors, particularly features of farm level, environmental factors and non-physical factors. These were classified into traditional as well as non-conventional factors. The impacts of macroeconomic variables like public investment and agro-ecological variables are identified by non-conventional factors. Conventional factors are traditional choice variables in the production decision process of the farmers. The conventional inputs include labor rate, fertilizer, and strength of tractor use while the non-conventional inputs include soil quality, irrigation, agricultural research, availability of calories, agricultural export growth (Frisvold and Ingram, 1994; Chiona, 2011). Some other studies have identified seed, plot size, herbicides, fertilizer, labour, manure, topdressing, fungicides as determinants of efficiency (Waluse, 2012).

Parikh *et al.* (1995) used two-stage estimation method to run a stochastic cost frontier in Pakistani Agriculture and found that schooling, number of working animals, credit per hectare and the number of extension visits significantly reduced cost inefficiency while the size of land holding and subsistence production significantly increased cost inefficiency.

Obwona (2006) used a one-step maximum likelihood procedure to analyse the determinants of technical efficiency differentials among small and medium sized tobacco growers in Uganda. The production function was estimated using a translog function simultaneously with the technical inefficiency effects. It was found that family size, education, credit accessibility and extension services contributed positively to improving efficiency among small and medium scale farmers. Farm-specific technical efficiency averaged 78.4 percent with a range of 44.5 percent and 98.1 percent, implying great variations in the level of efficiency among farmers.

Mbanasor and Kalu (2008) investigated the economic efficiency of commercial vegetable production system in Akwa Ibom State, Nigeria using a translog stochastic frontier cost function approach. They selected 150 vegetable farmers from whom data were obtained on input-output and their prices using the cost-route approach. The economic efficiency in the model was simultaneously estimated with the determinants. The study results showed a mean farm level economic efficiency of approximately 61 percent with a minimum of 13 percent and a maximum of 99 percent. The study found that level of education and household size adversely affected economic efficiency while age, farm experience, extension visit and credit access had a significant and direct effect on economic efficiency.

Rahman *et al.* (2009) identified factors such as socioeconomic and farm characteristics, environmental, physical and non-physical factors as some important determinants of technical inefficiency in agriculture for both the developed and developing nations.

Paudel and Matsuoka (2009) studied cost efficiency of maize production in the Chitwan district in Nepal and estimated all parameters of the stochastic cost frontier and the inefficiency model simultaneously. The study found that, education and maize area significantly decreased households' cost efficiency. The mean estimated cost efficiency was 1.634 with a range between 1.0 and 7.1. This implies that an average maize farmer in the study area incurred costs that are about 63 percent higher than the minimum cost specified by the frontier, meaning that over 63 percent of the costs of the maize farmer are wasted compared to the best practice firms producing the same output and facing the same technology. The estimated value of the efficiency scale was found to be greater than one, indicating that during maize production, a 1 percent increase in total cost of production would increase the total output of maize.

Chiona (2011) conducted a study to identify the mean technical and allocative efficiency and the determinants of inefficiency of smallholder maize farmers in Zambia. The research findings revealed that, smallholder farmers have less mean allocative and technical efficiency (13 farmers were fully technically efficient and 15 were fully allocatively efficient), while socio economic factors such as gender, education and farm size are important determinants of inefficiency. Again, the study revealed factors such as tillage after rains, use of recycled hybrid and local seeds, gender, dependency ratio, rearing of livestock, extension contact and fertilizer usage were found to significantly influence technical efficiency. Similarly, tillage after rains, farmers who had primary, secondary and university education, gender, livestock, farm size and fertilizer were factors that influenced allocative efficiency positively.

Waluse (2012) examined factors influencing the production of common bean and efficiency among 280 smallholder farmers in Eastern Uganda. The study employed a dual stochastic parametric decomposition technique to disaggregate components of economic efficiency and a double-stage limit Tobit model used to extract efficiency indices as a function of vectors of socio-economic and institutional characteristics. The mean technical efficiency among bean farmers was 48.2% mean economic efficiency was 59.94% and mean allocative efficiency was 29.37%. The result showed that farm size, asset value, extension service and group membership had a significant and positive impact on the bean farmers' technical efficiency. In the case of the economic efficiency, off-farm income in Ugandan Shilling (USh), asset value and credit were found to have significant influence on smallholder bean farmers' economic efficiency in Eastern Uganda.

Magreta *et al.* (2013) reported significant drop in economic efficiency of rice farmers in Nkhati irrigation scheme in Southern Malawi in spite of an increase in access to credit. The downturn was attributed to increases in household size and years of growing rice. The study revealed that technical, allocative and economic efficiency averaged 65.49 per cent, 59.41 per cent and 53.32 per cent respectively. Minimum and maximum technical efficiency was found to be 13.31 per cent and 93.23 per cent. Allocative efficiency ranged between 12.86 per cent and 91.23 per cent and economic efficiency indices were found to be between 12.41 and 89.93 per cent.

Abdulai *et al.* (2013), in a single estimation approach of technical inefficiency model for producers of maize in northern Ghana, found evidence of agricultural mechanization, experience in maize farming and gender to be negatively related to technical inefficiency. They revealed that, farmers without access to agricultural mechanization services were more technically inefficient (less technically efficient) than those who had access to and patronized agricultural mechanization services. For the sample maize farmers, the mean technical efficiency estimate was found to be 74 per cent with 12 per cent and 99 per cent being the minimum and maximum respectively. Increasing returns to scale was noticed, meaning maize production in the study area was in stage one of the production process during 2011/2012 cropping season.

In Edo state, Nigeria, Akhilomen *et al.* (2015) collected a cross-sectional data from 175 pineapple farmers to research on the economic efficiency of pineapple production. With the help of FRONTIER 4.1, the stochastic frontier production and cost function models were used in estimating the socio-economic characteristics and the inefficiencies of pineapple farmers. The mean technical, allocative and economic efficiencies of the farmers were 0.70, 0.68 and 0.64 respectively. Implying there is opportunities for increase in production by farmers. The estimates for the production function revealed decreasing returns to scale with a value less than one (0.52). Farming experience, extension visits and marital status were found to inversely influence farmers' economic inefficiency while gender and membership of cooperative society directly influenced economic inefficiency.

3.13.1 Empirical studies on Technical Efficiency of Tomatoes Production

The following empirical studies give an insight into the determinants of technical inefficiency in tomato production.

A study carried out by Asante *et al.* (2013) on the technical efficiency of tomato production in the Kwabere South District of the Ashanti region using stochastic frontier, indicated that education, gender and experience have a negative relationship with technical inefficiency. Hence, they tend to increase efficiency. Also, Donkoh *et al.* (2013) estimated technical efficiency of tomato production in northern Ghana using stochastic frontier. The study showed that farmers' level of formal education and farming experience had a significant negative relationship with inefficiency (hence a positive relationship with efficiency). They noted that educated farmers are equipped with requisite knowledge in the discretional use of modern technology, farm organization, and optimal utilization of farm inputs which increases their efficiency. Also, in the case of experience, they concluded that with more experiential knowledge, farmers effectively mobilize and appropriately use inputs and technology available to enhance efficiency.

Adenuga *et al*. (2013) conducted a study on the economics and technical efficiency of dry season tomato production in selected areas of Kwara state, Nigeria and also identified age, education and access to credit as the three exogenous variables that significantly increase the efficiency of tomato production in that State.

Ogunniyi and Oladejo (2011) conducted a study on the technical efficiency of tomato production in Oyo State, Nigeria. Gender and diversification were found to be significant and contributed positively to technical efficiency. On the other hand, experience had a negative relation with technical efficiency, which implies that efficiency decreases with increase in farming experience in that State. They found education, household size and marital status to be statistically insignificant in determining technical efficiency in their study.

3.14 Conclusion

From the literature review, it is realized that adoption of improved technologies is an essential tool for increasing agricultural productivity and farm household welfare, especially in developing countries where agriculture plays a dominant role in national economic development. From the empirical literature review, several socio-demographic and economic variables, farm-specific and institutional factors were identified as key determinants of technology adoption. On theoretical framework, a growing number of theoretical and empirical studies have been advanced to examine the welfare impacts of technology adoption, much of these studies employed the farm household model which posits that households maximise utility subject to income, production, and time constraints (Tambo & Wünscher, 2014). Random utility theory argues that individuals choose what they prefer based on what would provide the highest utility which some researchers employ to account for decision-making. Regarding impact assessment some studies adopted Propensity Score Matching (PSM) technique, first proposed by Rosenbaum and Rubin (1983) to evaluate the effect of technology adoption on the welfare of farmers that corrects for sample selectivity bias, but cannot correct endogeneity (Abdulai et al., 2018). Others employed the instrumental variables techniques such as the ESR or MESR.

However, from the review, it is found that only a few of these studies (including Abdulai & Abdulai, 2016; Issahaku, 2019) analysed the effects of adoption on efficiency, taking selection bias into consideration. Moreover, the few studies controlling for selection bias in efficiency effect of adoption only do so within the framework of binary treatment. In other words, none of these studies analysed the impacts of multiple technologies on technical efficiency. By way of extension, this study employs the multinomial endogenous switching regression in determining the factors influencing the adoption of ITSV and the impact of adoption on efficiency and welfare. Also, the review has revealed a consistency in the use of stochastic frontier model in the estimation of efficiency. Land, labour, fertilizer, seeds and pesticides were the dominant explanatory variables of farmers' outputs, while socio-demographic/economic and institutional factors were also found to affect famers' inefficiency.

CHAPTER FOUR

RESEARCH METHODOLOGY

4.0 Introduction

This chapter outlines the research methodology in seven (7) areas: the study area, the data collection approach, the sampling technique and sample size, the data analysis methods and presentation, empirical specification of models, *a priori* expectations and the description of variables used in the study.

4.1 Study Area

4.1.1 Background and Location

According to the United Nations Statistics Division (2018), Ghana is located in West Africa and has a total land area of around 238,540km^2 (92,101 mi^2). It shares borders with Burkina Faso in the North, the Gulf of Guinea in the South, Togo in the East and Cote d'Ivoire in the West. As of 1st January, 2018, Ghana's population was estimated at 29,088,849 people, showing a rise of 2.39 percent (679,273 people) compared to 28,409576 in 2017 (UNSD, GSS 2018)

Administratively, Ghana is divided into sixteen regions from the previous ten regions but ecologically remains divided into six zones (see Fig. 4.1). The six ecological zones are; Sudan Savannah, Guinea Savannah, Forest Savannah Transition, Semi-Deciduous Rainforest, High Rainforest and Coastal Savannah (Rhebergen *et al.*, 2016; Issaka *et al.*, 2012). The Guinea Savannah zone comprises the whole of Upper West, Northern region, North East Region, some parts of Upper East region, the northern part of Brong Ahafo region now Bono region and Volta regions. The zone has a single rainfall season spamming from May to October with yearly rainfall of about 1000 mm. The Sudan Savannah occupies the north-eastern part of Upper East region, now North East Region with a yearly rainfall of between 500 to 700 mm. The zone also has a single rainfall pattern lasting same period with the Guinea Savanna. The Forest Savannah Transition is located within the middle portion of Bono, Ahafo and Bono East region, the northern part of both Ashanti and Eastern regions and the western part of Volta region. This zone has a bimodal rainfall with an annual rainfall of averaging about 1200 mm. The Semi-Deciduous zone covers the northern part of Western region through southern Brong Ahafo, Ashanti and Eastern regions, eastern part of the Volta region and most parts of the Central region. It also has a bimodal rainfall with a yearly rainfall of 1400mm. High Rainfall zone occupies most parts of Western region with a small part of Central region. Annual rainfall in High Rainfall zone has a bimodal rainfall pattern with an annual rainfall of over 2000 mm. The Coastal Savannah covers the stretches from Central region through Greater Accra to the Volta region. It has a single rainy season of about 600 mm.

This study was carried out particularly in Guinea Savannah, Forest Savannah Transition and the Coastal Savannah zones. The reason for the selection of these three agro-ecological zones is motivated by a study by IFPRI (2013) which identified these zones as having the potential to grow enough tomatoes to meet domestic demand and supply excess for export to the neighboring countries. In Ghana, the agro-ecological zones have different climatic and environmental conditions which affect tomato production and yields. Tomato is moderately tolerant to a wide range of pH (level of acidity); it grows well in soils with a pH of 5.5 – 6.8 with adequate nutrient supply and availability. However, soils with very high organic matter content, like peat soils, are less suitable for tomato cultivation due to their high water holding capacity and nutrient.

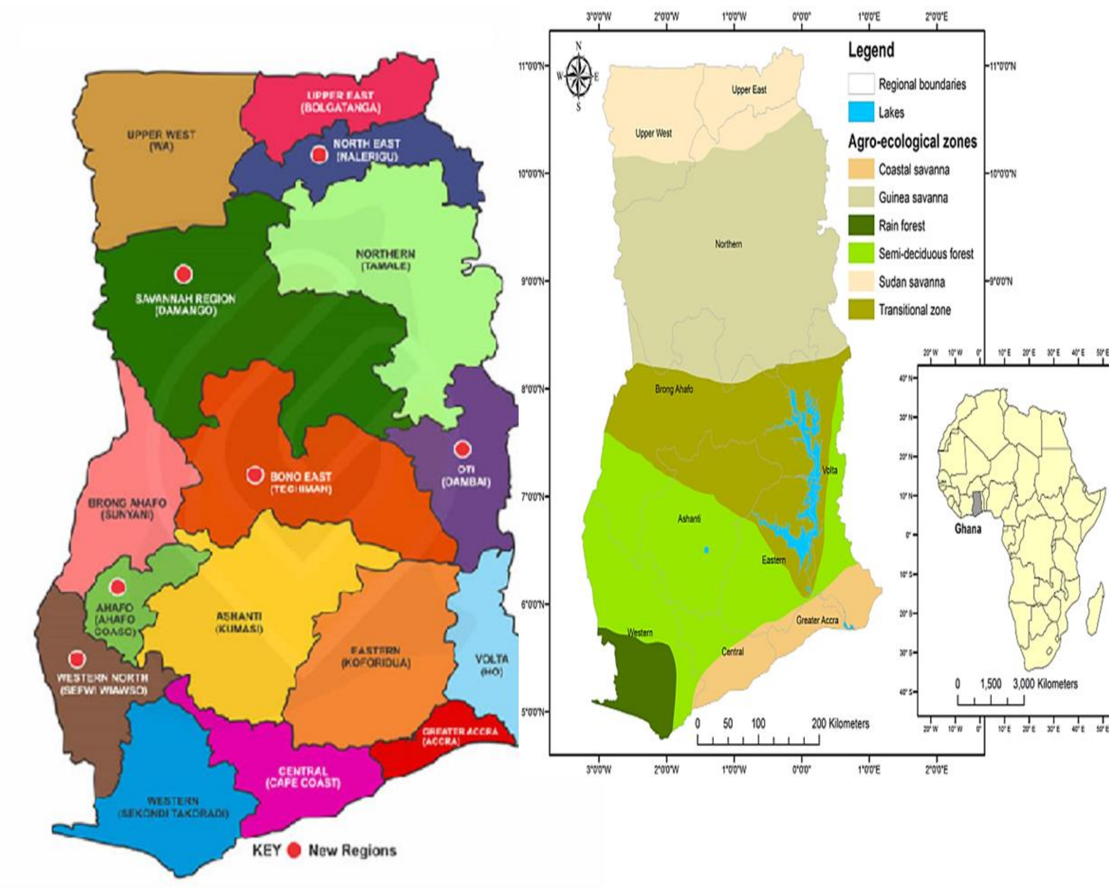

Figure 4. 1: Ghana map highlighting the 16 administrative regions and the agro-ecological zones

Source: GSS (2019) and Rhebergen et al. (2016)

Table 4. 1: Agro-ecological zones of Ghana

Agro-ecological zones	Region	Land Area [Km^2]	Average Annual Rainfall	Range of rainfall (mm)	Major rainy season
GSZ	UER, UWR, NR, NER, SR	147900	1000	800-1200	May-Sept (100-180 days)
FSTZ	BR, BER, VR, AR, ER	8400	1300	1100-1400	March-July (200-220 days
CSZ	CR, GAR, VR	4500	800	600-1200	March-July (100-110 days)
SSZ	UER, NE	2200	1000	600-1200	May-Sept (150-160 days)
HRFZ	WR, WNR	9500	2200	800-2800	March-July (150-160 days)
SDRFZ	AR, VR, BR, CR, WR.GAR	6600	1500	800-1600	March-July (150-160 days)
UER-Upper East Region, UWR-Upper West Region, NR-Northern Region, NER-North East Region, SR-Savanna Region, BR-Bono Region, BER-Bono East Region, VR-Volta Region, OR-Oti Region, AR- Ashanti Region, ER-Eastern Region, CR-Central Region, WR-Western Region, WNR-Western North Region, GAR-Greater Accra Region					

Source: *(MoFA, 2013)*

4.2 Research Design

The study is cross-sectional. A quasi-experiment design is used for the study i.e., both quantitative and qualitative methods of data collection and analysis was employed. The quasi experiement serves as a means for triangulating theories, data and methods (Aarons *et al.*, 2012; Landsverk *et al.*, 2012; Heale and Forbes, 2013). Quantitative research design deals with numerical data collection and statistical analysis to provide empirical evidences and inferences while the qualitative research design focuses on interviews and focus group discussions to gather and evaluate non-numerical or text data (Heale and Forbes, 2013).

4.3 Data Types and Sources

The study makes use of primary data. The primary data was solicited from tomatoes farmers and marketers in the various zones, using interview guides and semi-structured questionnaires containing both closed and open-ended questionnaires and administered through a face-to-face interview of respondents.

4.4 Sampling Techniques and Sample Size

Selection of the Study Area

A multi-stage sampling technique was used for this study. The study selected the Guinea Savanna, Forest Savanna Transition and Coastal Savanna based on the aforementioned IFPRI (2013) study. Stage 1 involved the use of purposive sampling technique to select one (1) municipality in the major tomatoes growing areas of the three selected ecological zones. Also, the 2nd stage involved the use of a stractified sampling technique to select five (5) communities in each Municipality. The communities were stratified based on the source of water for tomato cultivation: (a) cultivating tomatoes with dam water; (b) cultivating tomates with mechanized boreholes and (c) cultivating with rainwater. In the 3rd stage, a proportion-to-size sampling technique was used to select 30/20 households from each community based on tomatoes farming population of the municipality/district or community in a particular agro ecological zone.

Sampling of Household Respondents

In the 4th stage, a simple random technique was employed in the selection of individual respondent from each household engaged in tomatoes in the farming area. A representative sample size was determined to ensure that it is large enough to minimize the sample variance and biasness by ensuring the sample estimates equate the population parameters (unbiasedness). The target population for the study were tomato farmers in the selected communities. These farmers of tomatoes are assumed to have enough knowledge and experience in tomatoes production and marketing. The Slovin's formula used by Rivera (2007) was used in determining the sample size for the study. It is expressed as:

$$n = \frac{N}{(1 + Ne^2)}$$ **[32.0]**

Where n is the sample of farmers to be included in the study, N is the population size (number of potential farmers in Ghana, according to $MoFA(2016) = 2503006$) and e is the margin of error also known as precision level. This study used 4.4% as the margin of error. From the above formula, a total of 516 farmers regardless of acreage were obtained. Data was collected from the 516 respondents and was later cleaned to arrive at 508 farmers. A snowball sampling technique was also employed to select sixty five (65) traders of tomatoes for the study. This is shown in Table 4.2 and 4.2.1 below.

Table 4. 2: Sampling size of Farmer Household Respondents

Agro-ecological Zones	Metropolis/Municipal/District	Communities	Sample Size	Total
GUINEA SAVANNAH ZONE	Navrongo Municipal	Tono	30	150
		Nagalkina	30	
		Bonia	30	
		Vunania	30	
		Gani	30	
	Sagnarigu Municipality	Sagnarigu	20	100
		Kpalsi/Wurishe	20	
		Nyanshegu	20	
		Gurugu	20	
		Shishegu	20	
FOREST SAVANNAH TRANSITION ZONE	Techiman Municipal	Fiaso	30	158
		Ayeasu	30	
		Offuman	38	
		Mesedan	30	
		Bredi	30	
COASTAL SAVANNAH ZONE	Ashaiman Municipal	Roman Down	20	100
		Zenu	20	
		Lebanon	20	
		Newyork	20	
		Gbachele	20	
GRAND TOTAL				**508**

Source: Compiled by Author (2020)

Sampling of Market Actors

Marketing actors – wholesalers and retailers – were selected using the snowball sampling techniques from four major tomato originating and consuming markets in the respective agro-ecological zones. Techiman market in the FZTS which is both an originating and consuming market and also a strategic market in Ghana. Navrongo and Tamale markets in the GSZ, Navrongo market is major tomato originating market partially because of the Tono irrigation dam which makes it possible for all season production while Tamale market is a central consuming market in the GSZ. Ashaiman market in Accra was selected to represent the CSZ. This market is a central destination for tomatoes from different parts of the country to Accra. In all, a total of sixty-five (65) market actors were sampled from the various markets, consisting of thirty (32) wholesalers and thirty (33) retailers. The proportion of wholesalers and retailers for each market was based on the nature of the market; either it is predominantly an originating or a consuming market. The table below illustrates the sampling distribution across the selected markets.

Table 4.2.1 Sampling Size of Market Actors

Agro-Ecological Zones	**Markets**	**Nature of Markets**	**Wholesalers**	**Retailers**	**Total**
GUINEA SAVANNAH ZONE	Navrongo	Originating	10	5	15
	Tamale	Consuming	5	10	15
FOREST SAVANNAH TRANSITION ZONE	Techiman	Originating/ Consuming	12	8	20
COASTAL SAVANNAH ZONE	Ashaiman	Consuming	5	10	15
Total			32	33	**65**

Source: Compiled by Author (2020)

4.5 Data Processing and Analysis

As indicated already, the study employed both quantitative and qualitative techniques in the analysis. The Stata software version 16 was used to provide descriptive statistics, such as the mean, standard deviation and variance of the respondents' scores to all the statements in each of the sections of the questionnaire and to also estimate the maximum likelihood estimates of the technical efficiency. The test of significance was primarily performed at the probability level of $P < 5\%$ and $P < 10\%$ respectively.

Objectives one and two were determined using Multinomial Endogenous two-stage switching regression. Objective three and four of the study was estimated using the meta-frontier production function and the propensity score matching technique while accounting for selectivity bias. Objective five which was also aimed at determining the marketing efficiency and the determinants of marketing efficiency of farmers was determined by calculating the marketing margins, net margin and the determinants estimated with OLS.

4.5.1 Pre-Testing of Questionnaires and Test of Reliability of Survey Instrument

The pre-testing of the questionnaire was done in Tono and Offuman in the Guinea savanna and Forest savanna transition zones. A total of thirty (30) respondents consisting of fifteen (15) respondents each from a particular zone was used. A purposive sampling technique was used in selecting the two communities from the zones; simple random sampling technique was then used to select fifteen (15) tomato farmers from each of the above communities for the pre-testing. The response from the pre-tested questionnaire led to modifications of some questions; particularly the close ended questions were restructured as open ended. This gave more room for self-expression and opinion to some of the questions and some form of convergence in responses among respondents.

4.6 Empirical Specification of the Multinomial Endogenous Switching Regression (MESR)

As indicated earlier, the MESR model is suitable for analysing the determinants of ITSV adoption and the impact on farmers' welfare in the selected ecological zones in Ghana, given that the adopters of ITSV are in mutually exclusive categories. The first stage of the MESR model involves the use of a multinomial logit model to identify the socio-economic factors, influencing tomato farmers' decision to adopt a specific ITSV while the second stage measures the effect of adoption on welfare while correcting for possible sample selection.

Welfare measurement

To measure the welfare of farmers in the selected agro-ecological zones, three (3) indicators of welfare; total household income, expenditures and assets were used as a proxy for welfare in line with many studies (see H. Liet al., 2015; Mathengeet al., 2014; Michelson, 2013; Wossen 2017).

Total household income is expressed in current nominal terms comprising of net crop income (gross value of crop production less input cost); net livestock income (gross value of livestock production plus sales of live animal minus purchase of animals and input costs); salaried income; net business income and income from informal labour employment including on other farms and remittances; and pension and share dividends.

The total value of assets is expressed in current nominal values and consists of livestock; farm equipment; farm transport equipment; information and communication equipment and other household durable goods to be reported by the household while total household expenditure is also expressed in terms of total expenditure in the house on monthly basis.

Empirically, the multinomial endogenous selection and outcome models are expressed as:

(A) Improved Tomato Seed Variety adoption (selection) model

$$ITSV\_Adoption = \beta_0 + \beta_1 Sex + \beta_2 HH\_size + \beta_3 Edu + \beta_4 \Pr imary\_Occ + \beta_5 Income + \beta_6 Ext\_Contact + \beta_7 Credit\_access + \beta_8 Insurance\_Mem + \beta_9 Exper + \beta_{10} Cropping\_type + \beta_{11} FBO + \beta_{12} Potential\_yield + \beta_{13} Avail\_Maeket + \beta_{14} Seed\_access + \beta_{15} \operatorname{Re}s\_pest + \beta_{16} Early\_Maturity + \beta_{17} Storage\_ability + \beta_{18} \operatorname{Re}s\_badweather + \varepsilon_i \quad [33.a]$$

(B) Farmer Welfare (outcome) model is expressed as:

$$FW = \beta_0 + \beta_1 Sex + \beta_2 Age + \beta_3 HH\ size + \beta_4 Sec\ Edu + \beta_5 Tert\ Edu + \beta_6 \Pr imary\ Occ + \beta_7 Income + \beta_8 Ext\ Contact + \beta_9 Credit\ access + \beta_{10} Cropp\ type + \beta_{11} Pott\ yield + \beta_{11} Market\ avail + \beta_{12} Seed\ access + \beta_{13} Pest\ \operatorname{Re}sisExper + \beta_{14} Early\ Maturity + \beta_{15} Storage\ ability + \beta_{16} \operatorname{Re}sis\tan ce\ weather + \beta_{17} GSZ + \beta_{18} FSTZ + \varepsilon_i \quad [33.0b]$$

4.7 Empirical Group Stochastic Frontier and Technical Inefficiency Model

There is considerable debate about the selection of an appropriate functional form in SF modelling, with the Cobb-Douglas and translog forms being the most widely used (Abdul-Salam & Phimister 2017). As a result of its computational simplicity, the Cobb-Douglas functional form has been used most commonly. Given its flexibility, a translog functional form can be interpreted as a true representation of any underlying production frontier (Battese 1992). Based on this argument, and a likelihood ratio (LR) test that supported the translog functional form, we specified equation [36] using a translog specification.

Following Battese (1997) and Huang et al. (2014), the empirical model for group specific stochastic frontier for farmers in *k-th* ecological zone is expressed as:

$$
\begin{aligned}
&\ln T_i^k = \beta_0 + \beta_1 \ln Farmsize_i^k + \beta_2 \ln Seed_i^k + \beta_3 \ln Labour_i^k \\
&+\beta_4 \ln TractorService_i^k + \beta_5 \ln Fertilizer_i^k + \beta_6 \ln Herbicide_i^k + \beta_7 In\sec ticide \\
&+\frac{1}{2}\beta_8 (\ln Farmsize_i^k)^2 + \frac{1}{2}\beta_9 (\ln Seed_i^k)^2 + \frac{1}{2}\beta_{10} (\ln Labour_i^k)^2 + \frac{1}{2}\beta_{11} (\ln TractorService_i^k)^2 \\
&+\frac{1}{2}\beta_{12} (\ln Fertilizer)^2 + \frac{1}{2}\beta_{13} (\ln Herbicide)^2 + \frac{1}{2}\beta_{14} \ln(In\sec ticide_i^k) + \frac{1}{2}\beta_{15} \ln Farmsize * Seed_i^k \\
&+\beta_{16} \ln Farmsize * Labour_i^k + \beta_{17} \ln Farmsize * TractorService_i^k + \beta_{18} \ln Farmsize * Fertilizer_i^k \\
&+\beta_{19} \ln Farmsize * Herbicide_i^k + \beta_{20} \ln Farmsize * \ln In\sec ticide_i^k + \beta_{21} \ln Seed * Lobour_i^k \\
&+\beta_{22} \ln Seed * TractorService_i^k + \beta_{23} \ln Seed * Fertilizer_i^k + \beta_{21} \ln Seed * Herbicide_i^k + \\
&\beta_{22} \ln Seed * \ln In\sec ticide_i^k + \beta_{23} \ln Labour * TractorService_i^k + \beta_{24} \ln Labour * Fertilizer_i^k + \\
&\beta_{25} \ln Labour * \ln Herbicide_i^k + \beta_{26} \ln Labour * \ln In\sec ticide_i^k + \beta_{27} \ln TractorService * Fertilizer_i^k + \\
&\beta_{28} \ln TractorService * \ln Herbicide_i^k + \beta_{29} \ln TractorService * \ln In\sec ticide_i^k + \\
&\beta_{30} \ln Fertilizer * \ln Herbicide + \beta_{31} \ln Fertilizer * \ln In\sec ticide + v_i^k - u_i^k
\end{aligned}
$$

[34. 0a]

Where $\ln T_i^k$, denotes tomatoes output, β_0 to β_{31}, are unknown parameters of the production functions to be estimated, u_i^k are random errors assumed to be independent and identically distribute $N(0,\sigma^2{}_v)$, U_i^k are non-negative random variables, assumed to be independently distributed, measuring the technical inefficiency effect for the producer.

For a farmer to be technically efficient or inefficient will depend on some characteristics that are directly or indirectly associated with the farmer. These characteristics could be farmers' socioeconomic or demographic characteristics, farm specific location (FSD), institutional-policy variables (IPV), seed variety adoption (SVA) and the border town effect (BTE). Thus, technical inefficiency of the farmers in *k-th* agro-ecological zone is expressed theoretically as:

$$TI_i^k = U_i^k = \{\delta_o^k + \sum_{m=1}^{m=6} \delta_m^k FSD_{mi}^k + \sum_{m=7}^{m=10} \delta_m^k IPV_{mi}^k + \sum_{11}^{13} SVA_{mi}^k + \sum_{14}^{14} \delta_m^k BTE_{mi}^k + \delta_i^k\}$$

[35.0a]

Farmers' technical inefficiency is expressed empirically in the study as:

$$\begin{aligned} U_i &= \delta_0 + \delta_1 \ln Sex_m^k + \delta_2 \ln Age_m^k + \delta_3 \ln Educ_m^k + \delta_4 \ln HH\_Size_m^k \\ &+ \delta_5 \ln Mar\_Status_m^k + \delta_6 \ln Primary\_Occu_m^k + \delta_7 \ln Farming\_Exp_m^k + \\ &\delta_8 Cropping\_Type_m^k + \delta_9 \ln FBO_m^k + \delta_{10} \ln Credit\_Access_m^k + \\ &+ \delta_{11} \ln Ext\_Contact_m^k + \varepsilon_m^k \end{aligned} \quad \textbf{[35.b]}$$

Where the slope parameters are the $\delta_1, \delta_2, ..., \delta_{11}$ and the error term is ε.

4.7.1 Empirical estimation of the New-Two Step Stochastic Meta-frontier Translog Model

To estimate the new-two step stochastic metafrontier translog model, the group specific stochastic translog models are first estimated and each of these estimated group specific stochastic translog models are used in the prediction of tomatoes outputs. The group estimates of tomatoes output (T_i^*) are then pooled together and used for further estimation of the metafrontier model. Following the new two-step stochastic meta-frontier model used by Huang et al. (2014), the empirical stochastic meta-frontier translog model in this study is specified as:

$$\begin{aligned}
\ln T_i^k &= \beta_0 + \beta_1 \ln \text{Farmsize}_i^k + \beta_2 \ln \text{Seed}_i^k + \beta_3 \ln \text{Labour}_i^k \\
&+\beta_4 \ln \text{TractorService}_i^k + \beta_5 \ln \text{Fertilizer}_i^k + \beta_6 \ln \text{Herbicide}_i^k + \beta_7 \text{In sec ticide} \\
&+\frac{1}{2}\beta_8(\ln \text{Farmsize}_i^k)^2 + \frac{1}{2}\beta_9(\ln \text{Seed}_i^k)^2 + \frac{1}{2}\beta_{10}(\ln \text{Labour}_i^k)^2 + \frac{1}{2}\beta_{11}(\ln \text{TractorService}_i^k)^2 \\
&+\frac{1}{2}\beta_{12}(\ln \text{Fertilizer})^2 + \frac{1}{2}\beta_{13}(\ln \text{Herbicide})^2 + \frac{1}{2}\beta_{14} \ln(\text{In sec ticide}_i^k) + \frac{1}{2}\beta_{15} \ln \text{Farmsize} * \text{Seed}_i^k \\
&+\beta_{16} \ln \text{Farmsize} * \text{Labour}_i^k + \beta_{17} \ln \text{Farmsize} * \text{TractorService}_i^k + \beta_{18} \ln \text{Farmsize} * \text{Fertilizer}_i^k \\
&+\beta_{19} \ln \text{Farmsize} * \text{Herbicide}_i^k + \beta_{20} \ln \text{Farmsize} * \ln \text{In sec ticide}_i^k + \beta_{21} \ln \text{Seed} * \text{Lobour}_i^k \\
&+\beta_{22} \ln \text{Seed} * \text{TractorService}_i^k + \beta_{23} \ln \text{Seed} * \text{Fertilizer}_i^k + \beta_{21} \ln \text{Seed} * \text{Herbicide}_i^k + \\
&\beta_{22} \ln \text{Seed} * \ln \text{In sec ticide}_i^k + \beta_{23} \ln \text{Labour} * \text{TractorService}_i^k + \beta_{24} \ln \text{Labour} * \text{Fertilizer}_i^k + \\
&\beta_{25} \ln \text{Labour} * \ln \text{Herbicide}_i^k + \beta_{26} \ln \text{Labour} * \ln \text{In sec ticide}_i^k + \beta_{27} \ln \text{TractorService} * \text{Fertilizer}_i^k + \\
&\beta_{28} \ln \text{TractorService} * \ln \text{Herbicide}_i^k + \beta_{29} \ln \text{TractorService} * \ln \text{In sec ticide}_i^k + \\
&\beta_{30} \ln \text{Fertilizer} * \ln \text{Herbicide} + \beta_{31} \ln \text{Fertilizer} * \ln \text{In sec ticide} + v_i^k - u_i^k
\end{aligned}$$

[34.0b]

Note: All the other symbols and letters denote the usual parameters and variables in equation [34.0a], but measured here at the meta-frontier technical inefficient level of tomato farmers and denoted as U_i^*.

To obtain a meta-frontier technical efficiency ($METE_i$ or TE_i^*), the meta-frontier technical inefficiency is subtracted from one (1). Where a meta-frontier technical inefficient is given as:

$$TI_i^k = U_i^* = \left\{\delta_o^* + \sum_{m-1}^{m-6} \delta_m^* FSD_{mi}^* + \sum_{m-7}^{m-10} \delta_m^* IPV_{mi}^* + \sum_{11}^{13} SVA_{mi}^* + \sum_{14}^{14} \delta_m^* BTE_{mi}^* + \delta_i^* \right\} \quad \textbf{[35.0c]}$$

Implies ($METE_i = TE_i^* = 1 - U_i^*$).

The likelihood ratio test will be used in this study; the one-step maximum likelihood estimation procedure will be used to determine the relationship between tomato output (dependent variable) and input use (socio economic variables influencing tomato output). The generalized likelihood-ratio test is given as:

$$K = -2[\ln\{L(H_A)\}/\ln\{L(H_0)\}] = -2[\ln\{L(H_A)\} - \ln\{L(H_0)\}]$$ **[36.0]**

Where the values of the likelihood function under the alternative and null hypothesis are $L(H_A)$ and $L(H_0)$. Also, the value of K has a chi-square (χ^2) or the mixed chi-square distribution with the value of degrees of freedom equal to the difference between the number of parameters involved in H_A and H_0.

4.7.2 Testing of Efficiency Hypotheses

The hypotheses on efficiency were tested as follows:

1. $H_0 = \beta_i k = 0$, the null hypothesis identifies the right functional form between the restrictive Cobb-Douglas and the translog production function. It specifies zero equivalence in the cross terms

2. $H_0 : U = 0$, the null hypothesis states that each tomatoes farmer is producing on the technical efficient frontier and that the random and asymmetric technical efficiency in the inefficiency effects are zero. This is rejected when there is inefficiency.

3. $H_0 : \lambda = \delta_0 = \delta_2 = ...\delta_P = 0$, the null hypothesis specifies that the technical inefficiency effects are not present in the model at every level. This could be accepted or rejected based on the joint effect of explanatory variables on technical inefficiency

4.7.3 Accounting for technological heterogeneity and self-selection

. In this study, unlike those by Villano et al. (2015) and Issahaku and Abdulai (2020), where the decision variable is binary, the decision variable (ITSV) has more than two categories. Hence, we could not use the Greene (2010) approach which requires the decision variable (say ITSV) to be binary. The study therefore employed the Metafrontier technical efficiency based on technology difference to generate the MTE scores, then used the propensity score matching to match treated group (adopters) against the non-treated group (Non-adopters) who possess the same characteristics.

The impact of tomato seed variety adoption on the frontier production function and efficiency can differ due to the different yield potentials and complementary services associated with the technology package. To account for such a potential technological difference in the SPF model, along with its interactions with production inputs, denoted by $\ln XijITSVil$, the stochastic metafrontier (SMF) model was estimated. Following the works of Battese *et al.* (2004) and Geffersa et al. (2019), the econometric model for translog metafrontier production functions and selectivity correction is specified as follows:

$$\ln T_i = \beta_0 + \sum_{j=1}^{7} \beta_j \ln X_{ij} + \frac{1}{2}\sum_{j=1}^{7}\sum_{k=1x}^{7} \beta_{lk} (\ln X_{ij})(\ln X_{ik}) + u_i \ln \beta_{1i} + \phi_1 ITSV_i + \frac{1}{2}\sum_{j=1}^{7} \phi_j (\ln X_{ij})(ITSV_{ij}) + (v_i - u_i) \qquad \textbf{[37.0]}$$

$$\sigma_{ui}^2 = \exp(\delta Z_i^i) \qquad \textbf{[37.0a]}$$

$$\sigma_{vi}^2 = \exp(\eta Z_i^i) \qquad \textbf{[37.0b]}$$

Due to self-selectivity by the farmers, the decision variable, technology adoption (ITSV) when included in eqn (37.0) presents a likely endogeneity problem as the two groups of farmers (n the context of this study adopters and non-adopters of each seed variety) may differ in terms of certain household and farm characteristics.

To address this problem of endogeneity, the study employed a propensity score-matching (PSM) technique that accounts for differences in observed covariates between adopters and non-adopters of ITSV. The PSM estimates the probability or the propensity score (p-score) for the farmers based on certain characteristics. The empirical process for the estimation of the PSM in this study follows a three-step procedure. In the first step we estimated a probability model for producing ITSV and as well estimated p-scores for farmers adopting each of the four tomato seed varieties. Following the work of Imbens and Wooldridge (2009), the p-score is defined as:

$$p(y=1|X) \equiv \Pr(Ti=1|x_1, x_2........, x_j) = E[Ti|Xi] \qquad \textbf{[37.0c]}$$

where y is a response variable representing technology adoption, x denotes a set of explanatory variables for a given farm household, and T refers to a technology. The prediction of p-scores follows a non-linear binary (probit or logit) model:

$$ITSV_i^* = Z_i\alpha + \psi_i \text{ for } \{\text{ITSV}=\frac{1 if Z_i\alpha + u_i > 0}{0 otherwise}\} \qquad \textbf{[37.0d]}$$

where $ITSV_i$ is a binary variable as defined above, Z_i is a vector of factors that may influence farmers' adoption decision, and ψ_i is an error term assumed to be normally distributed with mean 0 and varience σ^2.

In the second step, we used the p-scores to compare the outcomes from adoption of a particular seed variety (treated) to the counterfactual situation, had they not adopted.

In the third stage, we matched the traditional variety (TMSV) subsample using the predicted p-scores to producers of ITSV. All traditional variety farmers were taken off from further analysis. Thus, an approximation of a situation was created in which the two groups of farmers could be comparable in terms of observable characteristics.

PSM is known to eliminate the baseline differences between farmers' adoption decisions. However, it fails to account for the unobservable variables that may influence the choice of technology. Thus, to minimise concerns about the potential unobservable heterogeneity that could influence the choice of tomato varieties, we included region dummies to control for potential region-level fixed effects.

4.8 Empirical Specification of Marketing Efficiency Formulas

According to Acharya (1988), marketing efficiency could be determined by using marketing margin. Where:

$$\text{Marketing margin} = \left(\frac{consumer\ price - producer\ price}{consumer\ price}\right) * 100\% \quad \textbf{[38.0a]}$$

Olukosi and Isitor (1990) however proposed an alternative formula for computing marketing margins as follows;

$$\text{Marketing margins} = \left(\frac{Valueadded\ \ by\ marketing\ \ activities}{Marketng\ \cos t}\right) * 100\% \quad \textbf{[38.0b]}$$

Sabu and Tripathy (1998) mentioned that minimum cost is the basis for efficient markets.

Gross Margin

Barnard and Nix (1979) reported that a venture's gross margin is its financial output minus its variable costs. The gross margin for the individuals in the supply chain of tomatoes will thus be measured as:

Gross margin=Total Revenue-Total variable cost

Also, Kohls (1985) stated that the marketing margin is equal to the difference between what the consumer pays and the farm gate per unit price of the food produce. From the above and on the assumption that farmers sell directly to wholesalers while wholesalers directly sell to retailers, wholesalers' gross margin equals: *wholesalers' selling price per unit minus farmers' selling price per unit while retailers' margin is equals to the retailers' selling price per unit minus wholesalers' selling price per unit***.**

Marketing margins are computed as follows:

$$GMM = (P_s - P_c)100 \qquad \textbf{[38.0c]}$$

Where GMM is the Percentage Gross Marketing Margin, P_s , is the average selling price of a particular player and P_c is the average cost price for the same player. The difference between the gross marketing margin and marketing costs is the *net margin* accrued to both the wholesaler and the retailer while the *marketing cost* is the sum of transport cost, storage cost, labor cost and other cost associated with carriage of the commodity from the point of purchase to the customer or the end user.

$$NMM = GMM - MC \qquad \textbf{[38.0d]}$$

Where a given traders Net Marketing Margin (*NMM)* is denoted by *MC* the trader's Marketing Cost.

4.9 Empirical Specification of the Ordinary Least Squares (OLS) Regression

A multiple linear regression model was also used to identify factors that influence tomato actors' marketing efficiency. The OLS technique was used to estimate model parameters since the dependent variable; marketing efficiency, is a continuous variable. The technique usually produces the best linear unbiased estimators (Koutsoyiannis, 1977). To maintain the data validity and robustness of the classical linear regression model (CLRM) the assumption of the model, the error term and the independent variable were considered.

These assumptions are, Linearity: The expected value of Y is linearly related to the X^s through the β parameters. Specification errors result when there is a nonlinear relationship, Independence: The independence of the X^s and e_i is necessary in order to identify the unknown β parameters, that is, in order to be able to solve for the β^s. $Cov(x_i, e_i) = 0$: The assumption is that, the $e's$ are independent and identically distributed which implies there should be no heterogeneity of variance and no autocorrelation among the residuals. Correct model specification; a specification error can occur when the model does not contain all of the relevant variables, that is the independent variables are measured without error, Normality: the error term e_i is normally distributed with mean (0) and constant variance.

The empirical model for analyzing the factors influencing marketing efficiency is stated as follows:

$$\begin{aligned}\mathrm{ME_i} &= \alpha_0 + \alpha_1 \mathrm{Sex_i} + \alpha_2 \mathrm{Educ_i} + \alpha_3 \mathrm{Farming\_Exp_i} + \alpha_4 \mathrm{FBO_i} \\ &+ \alpha_5 \mathrm{GSZ_i} + \alpha_6 \mathrm{FTSZ_i} + \alpha_7 \mathrm{Price\_Tomato_i} + \alpha_8 \mathrm{Cost\_Storage_i} + \\ &\alpha_9 \mathrm{Cost\_Transportation_i} + \alpha_{10} \mathrm{Postharvest\_Loss_i} + \xi_i \end{aligned} \quad \textbf{[39.0]}$$

Where the slope parameters are $\alpha_1, \alpha_2. \ldots \alpha_{10}$ and the error term is ξ

4.10 A *Priori* Expectations for Factors Influencing the adoption ITSV, tomatoes Outputs, TE, MFTE TI and ME

The explanatory variables, definitions, measurements and *a priori* expectations for the determinants ITSV adoption, tomato output in the stochastic translog frontier and the stochastic meta-frontier translog and inefficiency, and determinants of marketing efficiency are indicated in Table 4.3, 4.4, 4.5 and 4.6.

Table 4.3: Definitions, Measurements and *a priori* Expectations of Determinants of Tomato Seed Variety Adoption

Variable	Description	Measurement	*A priori* Expectation
			Improved varieties
Sex	Sex of the farmer	Dummy; 1 if the respondent is male, 0 if otherwise	+
HH_Size	Household size	No. of people eating from the same pot	+
Education	Education of the farmer	No. of years in school	+
Primary_Occupation	Main occupation of the farmer	Dummy; 1 if tomato farming is the main occupation, 0 if otherwise	+
Income	Annual household income	Ghana cedi	+
Ext_Access	Access to extension service	Dummy; 1 if the respondent had extension visit (s), 0 if otherwise	+
Credit_Access	Access to credit	Dummy; 1 if the respondent had credit, 0 if otherwise	+
Cropping_Type	Type of cropping	Dummy; 1 if the respondent practices mono-cropping, 0 if otherwise	+/-
Potential_Yield	Perception about yield	Scale; ranked from 1-7	+
Availability_Mkt	Perception about market access	Scale; ranked from 1-7	+
Seed_Access	Perception about access to seed	Scale; ranked from 1-7	+
Resistance_Pest	Perception about resistance to pest	Scale; ranked from 1-7	+
Early_Maturity	Perception about early maturity	Scale; ranked from 1-7	+
Storage_Ability	Perception about good storage ability	Scale; ranked from 1-7	+
Resistance_BadWeather	Perception about weather condition	Scale; ranked from 1-7	+
GSZ	Guinea Savannah zone	Dummy; 1 if the respondent is located in GSZ, 0 if otherwise	+/-
FTSZ	Forest Transition Savannah zone	Dummy; 1 if the respondent is located in FTSZ, 0 if otherwise	+/-
Instrumental variables			
FBO	Membership in FBO	Dummy; 1 if the respondent belonged to an FBO, 0 if otherwise	+
Insurance	Membership in insurance program	Dummy; 1 if the respondent participated in insurance program, 0 if otherwise	+

Table 4.4: Definitions, Measurements and *a Priori* expectation of Determinants of Tomatoes Output

Explanatory Variables	**Definition of variables**	**Unit of measure**	**Parameters**	***A priori* Expectations**	
				T_i^k	T_i^*
Farm size	Farmers' land size cultivated	Hectares	β_1	-	-
Seed	Quantity of seeds used	Grams	β_2	-	-
Labour	Quantity of labour	Man-Days	β_3	-	-
Tractor service	Farmers' Machinery service	Ghana cedis	β_4	+	+
Fertilizer	Quantity of fertilizer	Kilograms	β_5	+	+
Herbicides	Quantity of Herbicides	Litres	β_6	+	+
Insecticides	Quantity of Insecticides	Litres	β_7	+	+

Table 4. 5: Definitions, Measurements and *a Priori* Expectations of Determinants of Tomatoes Inefficiency

Inefficiency Variables	Definition of Variables	Measurement of Variables	*A priori* sign	
			T_i^k	T_i^*
Age	Farmers Age	Years	+/-	+/-
Sex	Sex of the farmer	Dummy; 1 if the respondent is a male, 0 if otherwise	+/-	+/-
Educ	Education of the farmer	Years		
HH_Size	Household size	Number of people	+/-	+/-
Mar_Status	Farmers marital status	Dummy; 1 if the respondent is married, 0 if otherwise	-	-
Primary_Occu	Primary occupation of the farmer	Dummy; 1 if tomato farming is the main occupation, 0 if otherwise	-	-
Farming__Exp	Farming experience	Years	-	-
Cropping_Type	Type of cropping	Dummy; 1 if the respondent practices mono-cropping, 0 if otherwise	-	-
Extension Contacts	Access to extension services	Dummy; 1 if the respondent had credit, 0 if otherwise	-	-
FBO	Membership in FBO	Dummy; 1 if the respondent belonged to an FBO, 0 if otherwise	+/-	+/-
Credit_Access	Access to credit	Dummy; 1 if the respondent had extension visit(s), 0 if otherwise	-	-

Table 4.6: Definitions, Measurements and *a Priori* Expectations of Determinants of Tomato farmers Marketing Efficiency

Variables	Definition of Variables	Measurement	A priori Expectation
Sex	Sex of the farmer	Dummy; 1 if the respondent is a male, 0 if otherwise	+
Education	Farmer's Level of Educational	Number of years	+
Farming_Exp	Farming experience	No. of years	+
FBO	Membership in FBO	Dummy; 1 if the respondent belonged to an FBO, 0 if otherwise	+
GSZ	Guinea Savannah zone	Dummy; 1 if the respondent is located in GSZ, 0 if otherwise	+/-
FSTZ	Forest Transition Savannah zone	Dummy; 1 if the respondent is located in FTSZ, 0 if otherwise	+/-
Price of Tomato	Price of tomato	Ghana Cedi	+
Cost of Storage	Cost of storage	Ghana Cedi	-
Cost of Trans	Cost of transportation	Ghana Cedi	-
Postharvest Loss	Cost of postharvest losses	Ghana Cedi	-

CHAPTER FIVE

DESCRIPTIVE STATISTICS OF THE STUDY

5.0 Introduction

This chapter presents the results and discussion of the descriptive statistics of the study. The result includes; the characteristics of the farmer and the farm-specific features, as well as institutional and environmental factors use in the study, household income by economic activities; household expenditure on food and non-food commodities; summary statistics of socio-demographic and economic characteristics and institutional factors used in the analysis of ITSV adoption.

5.1 Farmer and Farm-Specific Characteristics

Table 4.7 shows the descriptive results of the farmer and farm-specific characteristics, as well as institutional and environmental factors used in the study. As shown in the table, the respondents have a mean age of 40.53 years with a minimum of 22 years and a maximum of 77 years respectively. The mean ages of farmers in GSZ, FSTZ, and CSZ are 41.09 years, 40.97 years, and 39.367 years. These statistics imply that tomato farmers are within their active and economical years and this has the tendency of increasing tomatoes production in the country. This finding is consistent with the Dasmani *et al.* (2020) study which showed a mean age of 40 years. Also, about 89.6% of the respondents are male while the remaining 10.4% are females. The sex distribution in GSZ (73.4%), FSTZ (87.0%), and CSZ (84.1%) also suggest that tomato production is dominated by males. The findings are consistent with Owusu (2016), Wongnaa and Awunyo-Vitor (2019), and Dasmani *et al.* (2020) who revealed male dominance in farming in the coastal, forest and savannah zones in Ghana. It was also revealed that the dominant 82.10% in cormmercial tomato farming are males with on a few females 17.90 also in commercial tomato faming. However, in the case of small-scale farming, majority 91.29% are female with the remaining 8.71% being males. This finding does not meet the *a-priori* expectation, since a higher percentage of women are in commercial production than in subsistent/small-scale. The finding however, may be attributed to the fact that women are at the center stage of household cooking, thus growing the tomatoes in small scale for household consumption.

The survey results show that 36% of the sampled respondents in the selected agro ecological zones are illiterate while the remaining 64% are literate. The mean formal education is 2.23 years with a minimum of zero and a maximum of seven. The results also show a low level of formal education in GSZ (2.21 years), FSTZ (2.74 years), and CSZ (1.50 years) respectively. The mean educational years also indicate that the highest level of education a respondent has attained on average is primary education (approximately Primary 3). The result is consistent with the GSS (2016) finding which indicates approximately half of Ghana's adults not to have obtained primary education or completed middle school/JHS. In terms of technology adoption and understanding of market dynamics this could have some negative influence on agriculture. According to Minot et al. (2006), education is also a means of accessing extra employment activities, especially in the non-farm sector. Moreover, majority (90%) of the family heads of the selected farmers in the agro ecological zones are without formal education and this may mean that most of these people would not be able to engage in any formal employment except agriculture. The findings are consistent with (Dasmani et al., 2020).

Table 5.1: Descriptive statistics of the sample's characteristics

	GSZ (n=250)		FSTZ (n=158)		CSZ (n=100)		Pooled (n=508)	
Variables	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Farmer characteristics								
Gender (dummy)	0.896	0.306	0.734	0.443	0.870	0.338	0.841	0.366
Age (years)	41.092	11.054	39.367	8.554	40.970	11.854	40.532	10.522
Household size (count)	7.488	3.662	6.677	10.693	9.250	4.774	7.583	6.874
Education (years)	2.208	2.426	2.741	1.130	1.500	1.806	2.234	2.027
Farming experience (years)	14.060	9.809	11.285	7.451	13.090	10.744	13.006	9.406
Primary occupation (dummy)	0.848	0.360	0.930	0.255	0.670	0.473	0.839	0.368
Policy variables								
Membership in FBO (dummy)	0.984	0.126	0.962	0.192	0.920	0.273	0.965	0.185
Membership in insurance policy (dummy)	0.080	0.272	0.050	0.219	0.000	0.000	0.049	0.217
Extension service (dummy)	0.436	0.497	0.816	0.388	0.830	0.378	0.632	0.483
Access to credit (dummy)	0.184	0.388	0.038	0.192	0.100	0.302	0.122	0.328
Production variables								
Land size (ha)	2.375	1.693	2.441	1.534	2.946	2.382	2.508	1.814
Farming type (dummy)	0.252	0.435	0.481	0.501	0.500	0.503	0.372	0.484
Labour (mandays/ha)	86.400	66.374	207.278	217.504	134.200	90.265	133.406	145.583
Seed (g/ha)	230.956	97.998	240.430	98.879	225.500	93.263	251.935	99.936
Tractor service (GH¢/ha)	278.720	112.011	230.057	95.178	273.456	101.349	214.029	92.303
Fertilizer (kg/ha)	252.204	251.348	410.127	404.149	239.010	381.616	298.724	340.120
Herbicides (litres/ha)	6.562	12.035	3.425	4.155	1.824	0.975	4.654	8.973
Insecticides (litres/ha)	3.847	4.155	3.134	2.618	1.725	0.907	3.207	3.376
Output (crates/ha)	94.060	70.524	98.070	67.778	109.350	89.909	98.317	74.005
Environmental factors								
Annual rainfall (mm)	984.1	870	1150	1000	841.3	800	1024	800
Annual temperature (^{o}C)	28.5	27.8	26.7	26	24.6	24	27.1	24

Source: Computed from Household Survey Data, 2020

The mean farming experience is 13.01 years. The average farming experiences of farmers in GSZ, FSTZ, and CSZ are 14.06 years, 11.28 years, and 13.09. The findings suggest that tomato farmers have gained a fair experience in tomato production. This high level of expertise in farming can be an essential factor for improving the efficiency of resource use in tomato production.

The mean household size is 7 persons per household with a minimum of one and a maximum of twenty-three respectively. This average is about equal to the average of 7.7 members in Ghana's household (GSS, 2010). The average household sizes of farmers in GSZ, FSTZ, and CSZ are 7.49, and 6.68, and 9.25. This finding is in-line with the findings by GPHS (2010), which revealed Ghana to practice extended family system where a household has an average population 5 or more. Martey *et al.* (2012) indicated that large household sizes necessitate adequate supply of family labor. Al-Hassan (2008) also argues that large families enable members of household to earn additional income from non-farm activities and can help minimize marketable surplus through consumption.

Furthermore, majority (83.9%) of the farmers are engaged in tomato production as their primary occupation. For agro ecological zones, a higher number of farmers in FSTZ (93.0%) and GSZ (84.8%) are engaged in tomato production as their main source of livelihood, compared to those in CSZ (67.0%). This finding could be attributed to lack of formal education of the sample respondents. It is common to find many who are not formally educated engaged in informal jobs such as farming, craftsmanship, petty trading and others.

Table 5.1 further reveals that the mean land size is 2.51 ha for the pooled sample and 2.95 ha, 2.44 ha, and 2.38 ha in CSZ, FSTZ, and GSZ. The findings suggest that tomato farmers are primarily working on smaller plots and can be termed as smallholders. A smaller percentage (37.2%) of the sample engaged in mono-cropping, compared to mixed cropping. However, mono-cropping in tomato production is high among farmers in CSZ (50.0%), followed by farmers in FSTZ (48.1%) and GSZ (25.2%).

Labour is another important variable that is required through the production process. The mean labour for the pooled sample was approximately 133.41 mandays/ha, with a minimum of 10 and a maximum of 1200 mandays. The mean labour employed in FSTZ is (207.28 mandays/ha) and happens to be higher than the average labour employed in CSZ (134.20 mandays/ha) and GSZ (86.40 mandays/ha).

The average quantity of seed planted to one ha was estimated at 251.935g for the pooled sample. However, the average seeds planted in GSZ is 230.956g, compared to those in FSTZ (240.430g/ha) and CSZ (225.500g/ha). The mean fertilizer application rate is also 298.72 kg/ha.

The mean herbicide and insecticide application rates are 4.654 litres/ha and 3.207 litres/ha for the entire farmers respectively. The results also show that the average herbicide and insecticide application rates are higher in GSZ than in FSTZ and CSZ.

The average cost of tractor services is GH¢214.03/ha for the pooled sample. However, farmers in GSZ spend more on tractor services (GH¢278.72/ha), followed by those in CSZ (GH¢6273.46/ha) and FSTZ (GH¢230.06/ha). Tractor services cost was found to differ among the agro-ecological zones. The study findings revealed larger production (ha) in terms of land cultivation, easy accessibility to tractor services to account for the differences in tractor service prices. Farmers who cultivate tomatoes in larger quantities tended to have lower price for tractor service compared to farmers who cultivate tomatoes in smaller quantities since they enjoy economy of scale. It was also revealed that, a lot of farming activities (rice, maize and other crops) goes on in the GSZ relative to the CSZ, hence most tractor owners move their tractors to the GSZ for ploughing making it difficult to have access to tractor services in the CSZ.

The mean output of tomato for the entire sample is estimated at 98.32 crates per ha. A crate was evaluated at 72kg. Tomato output is also higher in CSZ (109.35 crates/ha than in FSTZ (98.07crates/ha) and GSZ (94.06crates/ha). The study findings revealed access to credit from both formal and informal sources for farmers in CSZ to account for higher output compared to the FSTZ and GSZ who have little access to credit from only the informal sources.

Table 5.1 also shows farmers' access to extension services, membership in FBOs, and environmental factors such as annual rainfall and annual temperature. The table reveals that about 96.5% of the farmers belonged to FBOs. The proportions of FBO members in GSZ, FSTZ, and CSZ are 98.4%, 96.2%, and 92.0%. FBOs act as platforms through which farmers get to identify new technologies, ideas and credit to mitigate current and future problems related to the acquisition and use of farm inputs, and marketing imperfections to ascertain other important and essential agricultural knowledge through training and demonstration (Osman *et al.*, 2018).

Furthermore, about 63.2% of tomato farmers have access to extension services. However, access to extension services is higher in CSZ (83.0%) and FSTZ (81.6%), compared to GSZ (43.6%). The findings suggest that most tomato farmers are more likely to be introduced to technical advice and new technologies needed to increase tomato production and farm income due to their low access to extension services. Just 12.2% of the entire farmers have access to credit for their tomato production. The proportions of farmers with access to credit in GSZ, FSTZ, and CSZ are 18.4%, 3.8%, and 10.0% respectively.

Also, less than 5.0% of the entire sample belongs to an insurance program. About 8.0% and 5.0% of farmers in GSZ and FSTZ belong in an insurance program, whereas none of the farmers in CSZ participated in an insurance program.

5.2 Summary statistics of variables used in the MESR Model

The means and standard deviations of variables used in the MESR model are presented in Table 5.2 The mean age of TMSV, PRSV, and PSV adopters are 38.947years, 41.384, and 40.232 years respectively. The average farming experiences are 12.032 years, 13.397 years, and 13.000 years for TMSV, PRSV, and PSV. The mean education is uniform for TMSV, PRSV, and PSV adopters. The mean monthly income of households is also GH¢673.553, GH¢597.755, and GH¢705.497 for TMSV, PRSV, and PSV adopters. The proportion of tomato farmers in FBOs and those with access to credit and extension services is low. Memberships in FBOs, access to credit and extension services are measured as dummy variables. About 50% of the farmers engage in irrigation farming. Also, farmers adopted improved TSV based on pest resistance, followed by the low cost of seed, high adaptability to weather conditions, ready market, early maturity, easy accessibility to the seed source, and good storage ability.

Table 5.2: Summary Statistics of Variables in MESR Model, by Variety

	TMSV		PRSV		PSV		PSV/PRSV	
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Age	38.947	9.783	41.384	11.180	40.232	9.918	39.947	9.983
Farming Ex	12.032	8.338	13.397	9.887	13.000	9.291	13.012	8.338
Education	2.415	1.780	2.059	2.152	2.373	1.968	2.159	2.252
Total Income	673.553	638.380	597.755	559.506	705.497	520.298	600.755	501.506
Primary Ocu	0.809	0.396	0.823	0.383	0.876	0.331	0.811	0.369
Cropping Type	0.404	0.493	0.367	0.483	0.362	0.482	0.437	0.513
Membership in FBO	0.979	0.145	0.970	0.170	0.949	0.220	0.770	0.070
Membership in Insurance Policy	0.032	0.177	0.068	0.251	0.034	0.181	0.132	0.277
Credit Access	0.085	0.281	0.148	0.356	0.107	0.310	0.185	0.381
Extension Contact	0.637	0.482	0.634	0.484	0.544	0.501	0.337	0.382
Potential Yield	0.479	0.502	0.489	0.501	0.540	0.500	0.477	0.510
Market Availability	3.691	2.636	2.743	2.191	3.747	2.593	3.944	2.573
Seed Access	3.926	2.591	2.882	2.199	3.787	2.557	3.887	2.657
Pest Resistance	2.883	1.945	2.793	1.879	3.045	2.072	3.145	2.172
Early Maturity	2.617	1.890	2.844	1.789	3.183	1.968	2.517	1.790
Storage Ability	2.628	1.697	3.055	1.975	2.994	1.890	2.728	1.791
Resistance to Bad Weather	2.957	2.165	3.072	2.298	3.582	5.124	2.759	2.1535

Source: Author’s Estimations from Field Survey, 2020

5.3 Household Welfare Analyses

5.3.1 Household Income across the Agro-ecological Zones

Welfare is operationalized in this study as the wellbeing of farmers, taken into consideration the farmers' infrastructure, social status and the available social amanities at the farmers' services (GSS, 2014). Following the works of (see H. Liet al., 2015; Mathengeet al., 2014; Michelson, 2013; Wossen 2017), welfare indicators such as; total household income, total household expenditure and total fixed assets were used as proxy variables to represent farmers welbeing The total household income of farmers was determined by aggregating income from agriculture (including tomato production, livestock rearing, forestry and aquaculture), formal employment, and non-farm/informal employment (both own and hired) in the production year. Figure 5.1 shows the average tomato income and household income by agro-ecological zones. Household income, measured in Ghanaian cedes (GH¢), was evaluated as the sum of income from agriculture (including tomato production, livestock rearing, forestry, and aquaculture), formal employment, and non-farm/informal employment in the production year. The figure indicates that the mean annual tomato income and total annual household income of the entire sample are estimated at GH¢3918.9 and GH¢ 15443.2 respectively. Further analyses reveal that mean household income in FSTZ (GH¢30733.6) is more than household income in CSZ (GH¢9862.2) and GSZ (GH¢8012.2). Also, tomato income in FSTZ (GH¢5369.9) was more than household income in GSZ (GH¢3640.6) and CSZ (GH¢2322.4). The finding suggests that tomato farm households in FSTZ are better off, compared to those in GSZ and CSZ. This finding could be attributed to large scale production of tomatoes in the FSTZ as a result of easy access to credit from both the formal and the informal sources for tomato farmers in FSTZ compared to GSZ and CSZ farmers who mostly have a single source (informal) to access credit. Also, the findings could be attributed to cheap labour in the FSTZ compared to the GSZ and the CSZ. Mostly, many youth in the GSZ live to settle at the FSTZ for greener pastures, thus making it cheap for labour services in this zone and in turn create labour deficit in the GSZ, making labour services costly.

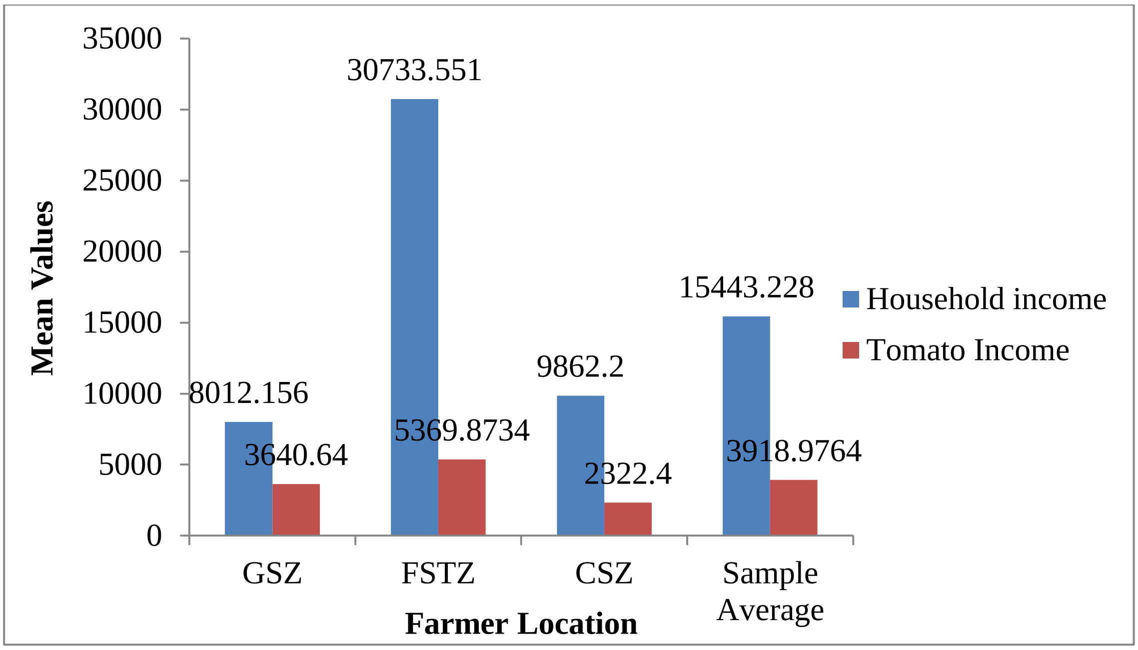

Figure 5. 1: Summary of household income by agro-ecological zones

Source: Author's Estimations from Field Survey, 2020

5.3.2 Household Expenditure of Tomato Farmers in the Agro-ecological Zones

Household expenditure, also measured in Ghanaian cedis (GH¢), is evaluated as the sum of cash expenditures on food commodities (including the estimated value of own production) and non-food commodities. As shown in Table 5.3, the mean annual household expenditure is estimated at GH¢8895.6, with food expenditure accounting for about GH¢3251.6 (36.55%). Regarding the non-food commodities, a greater amount of cash was spent on children's education (GH¢1550.5), followed by utilities (GH¢799.6); clothing (GH¢749.9), housing (GH¢706.2), transportation (GH¢518.7), health care (GH¢406.0), and fuel (GH¢199.6). The results of the one-way analysis of variance (one-way ANOVA) further show that household expenditure in FSTZ (GH¢11135.9) was significantly higher than those in GSZ (GH¢8002.6) and CSZ (GH¢7588.9). Also, households in FSTZ spent more money on food and non-food commodities such as fuel, transportation, education, utilities, clothing, housing, and healthcare, compared to households in GSZ and CSZ. This finding could be attributed to the rational behavior of consumers, where if all other consumption determinants are held constant, as one's income increases one's consumption increases. Thus, since FSTZ has more income from all-year round production, it is expected that its expenditure on both food and non-food commodities should be more than that of GSZ and CSZ.

Table 5.3: Results of Annual Household Expenditure

Item	Pooled sample Mean (GH¢)	GSZ Mean (GH¢)	FSTZ Mean (GH¢)	CSZ Mean (GH¢)
Food	3251.565	2932.0	3722.96	3303.43
	(1682.036)	(1079.29)	(1339.32)	(2846.20)
Fuel (Gas)	199.575	88.46	306.49	192.48
	(142.880)	(1874.55)	(1589.16)	(1577.48)
Transportation	518.707	362.06	860.0	370.7
	(948.380)	(588.77)	(1332.93)	(804.5)
Education	1550.484	1988.0	1236.4	952.52
	(1649.605)	(1936.71)	(1243.97)	(1022.05)
Utilities (Water /	799.560	723.5	115.8	491.17
Electricity/Communication)	(1342.881)	(1680.41)	(971.55)	(605.38)
Clothing	749.990	471.83	619.88	522
	(1541.475)	(474.22)	(563.3)	(833.92)
Housing	706.2001	503.83	842.63	996.58
	(1504.467)	(637.40)	(893.22)	(3014.3)
Health Care	406.023	332.29	623.96	246.0
	(579.386)	(330.3)	(886.5)	(287.96)
Total Household Expenditure	8895.597 (6394.805)	8002.62 (5394.0)	11135.95 (72.75.76)	7588.9 (6366.64)

NB: Figures in brackets are standard deviation

Source: Author's Estimations from Field Survey, 2020

CHAPTER SIX

FARMERS' ADOPTION OF IMPROVED TOMATO SEED VARIETY (ITSV) AND HOUSEHOLD WELFARE ANALYSES IN SELECTED AGRO-ECOLOGICAL ZONES IN GHANA

6.0 Introduction

This chapter presents the results and discussion of improved tomato seed variety adoption and its impact on household welfare of farmers in selected agro-ecological zones in Ghana. To measure household welfare impacts of tomato seed variety adoption in the selected agro-ecological zones, total income, total expenditure and total assets of the household, measured in Ghana Cedi are used. The results include frequency distribution and graphical representation of improved tomato seed variety adoption across the selected agro-ecological zones; determinants of ITSV adoption; and impact of ITSV adoption on household welfare. The results are obtained by applying both descriptive statistics and econometric models using primary data obtained from a random sample of 508 farmers.

6.1 Tomato Seed Variety Adoption across the Agro-ecological Zones

Table 6.1 provides the distribution of respondents according to improved tomato seed variety (ITSV) adoption. The predetermined ITSV improved were Pectomer seed variety (PSV), Power Roma seed variety (PRSV) or a combination of the two and the local variety (Techiman seed variety (TMSV). While assuming mutual exclusiveness in adoption, the categorization of the tomato seed variety adoption was based on proportion of adoption, should a farmer adopt more than 50% of a particular seed, he/she is said to have adopted that seed relative to the other. In the case of joint adoption 50-50 proportion of adoption is allocated to both seeds. On the bases of mutually exclusiveness of the seed variety, the multinomial logit was estimated rather than a multivariate logit model. The results reveal that the highest proportion (40.55%) of farmers adopted PSV, followed by those who adopted PSV/PRSV (32.28%), PRSV (21.46%), and the traditional variety TMSV (5.71%). The two improved tomato seed varieties have similar characteristics in terms of size and means of cultivation but may have different potentials in terms of early maturity and other agro-ecological specific characteristics.

Table 6.1: Tomato Seeds Adoption

Improved Tomato	Frequency	Percentage (%)
Pectomech	206	40.55
Power Roma	109	21.46
Pectomer /Power Roma	164	32.28
Non-Adopters(“Techiman”)	29	5.71
Total	508	100.0

Source: Computed from Household Survey Data, 2020.

Figure 6.1 also shows improved tomato seed variety adoption by farmers across the three agro-ecological zones. In the figure below, the distributions of respondents according to improved tomato seed variety adoption are identical across the three agro-ecological zones. For the farmers in GSZ, about 42.4% adopted PSV/PRSV, while 33.2%, 17.6% and 6.8% adopted PSV, PRSV and traditional variety, TMSV, respectively. Similarly, for the farmers in FSTZ, 26.6% adopted PSV/PRSV whereas 32.3%, 38.6% and 2.5% adopted PSV, PRSV and the traditional variety TMSV respectively. Furthermore, about 16.0% of CSZ farmers adopted PSV/PRSV, while 72.0%, 4.0%, and 8.0% adopted PSV, PRSV, and traditional variety TMSV, respectively. The results generally suggest that farmers cultivate more improved varieties compared to the local variety in the various agro-ecological zones in Ghana. This finding could be attributed to the fact that the improved varieties have good varietal characteristics compared to the local variety.

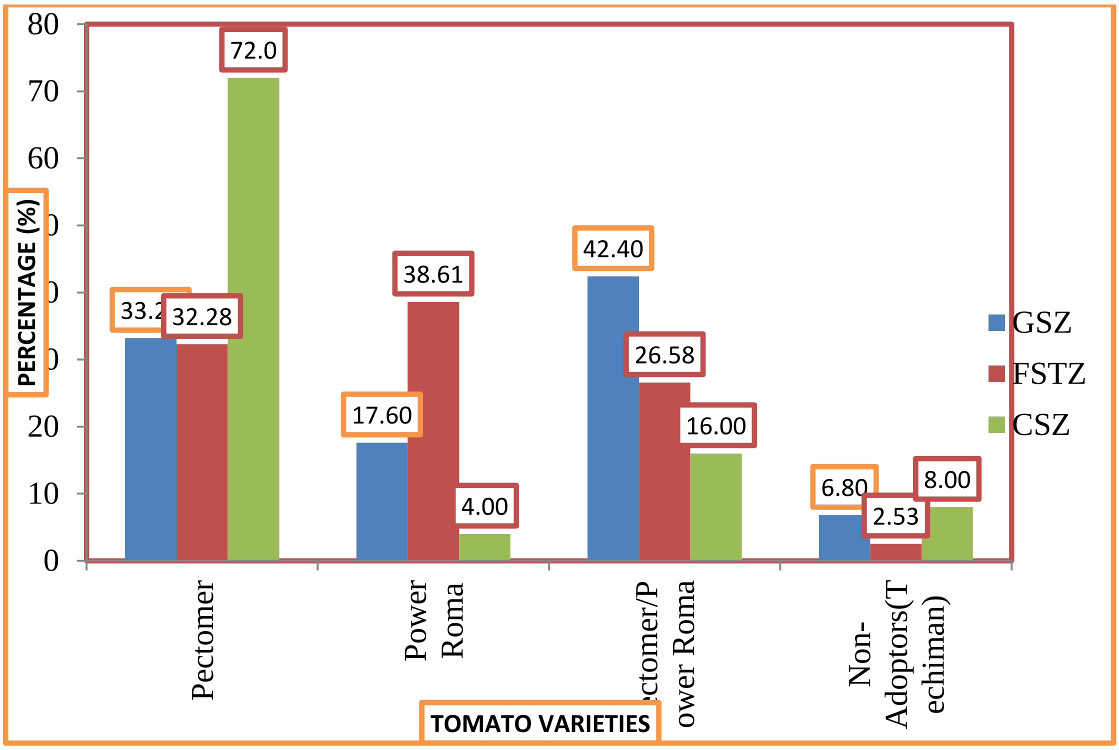

Figure 6.1: Improved Seeds Adopted in Various Agro-Ecological Zones

Source: Author's Estimations from Field Survey, 2020

6.2 Farmers' Motives for Adopting Improved Tomato Seed Variety

Understanding farmers' motivations is important for stimulating the adoption of new and improved technologies and the goals that they seek to achieve (Greiner and Gregg, 2011; Veisi *et al.*, 2017). According to Peterson *et al.* (2012), farmers have more than a single reason for adoption. Table 6.2 shows the five most important reasons driving the adoption of tomato seed varieties; PSV, PRSV, and TMSV. Farmers who adopted PSV stated high-yielding capability, access to a ready market, resistance to pests, early maturity, and availability of seed as their five most important reasons for adopting the variety.

Those who adopted PRSV also ranked resistance to pests, good storage ability (longevity), resistance to bad weather, access to extension, and early maturity as their five most important reasons for adoption.

Also, farmers who stuck to the traditional variety TMSV ranked good storage ability (longevity), early maturity, pest tolerance, high-yielding capability, and access to extension as the five most important reasons for adopting it. The finding is consistent with previous studies (Kamara *et al.,* 2006; Asrat *et al.,* 2010; Sibiya *et al.,* 2013; Veisi *et al.,* 2016) who reported that resistance to pest and disease infestation, higher and stable yields, and low post-harvest losses are important risk factors driving farmers' adoption of improved seed varieties. Timu *et al.* (2014) examined the role of varietal attributes on the adoption of improved sorghum seed varieties in Kenya and found that drought tolerance and yield were some of the reasons driving rapid adoption. In Ghana, Acheampong *et al*. (2013) also reported that longevity and resistance to diseases are important attributes for farmers' adoption of cassava varieties. Access to high-yielding variety is also important for improving agricultural productivity and food security (Chandio and Yuansheng, 2018). Sánchez-Toledano *et al.* (2018) also argued that the provision of improved seeds is among the key strategies to improve crop yields in most developing countries. Adequate provision of extension information that creates awareness of the potential benefits of improved seed varieties could increase tomato farmers' adoption.

Table 6.2: Reasons for Improved Tomato Seed Adoption

Variable	Mean Values	Std. Dev.
Pectomech		
Higher yield	2.619231	2.146474
Access to a ready market	2.784615	2.195062
Resistance to pests	2.819231	1.85008
Early maturity	2.841699	1.783331
Availability of seed	2.933852	2.225452
Power Roma		
Resistance to pests	2.994048	2.120606
Good storage ability (longevity)	3.094675	1.988786
Resistance to bad weather	3.213018	2.212426
Access to information	3.221557	2.465182
Early maturity	3.27381	1.996111
Techiman		
Good storage ability (longevity)	2.392405	1.52263
Early maturity	2.417722	1.808864
Resistance to pests	2.949367	1.967028
Higher yield	2.987342	2.534347
Access to extension service	3.038462	2.287415

Source: Author's Estimations from Field Survey, 2020

6.3 Factors Explaining Farmers' Adoption of Improved Tomato Seed Variety

A multinomial logit is estimated to examine the determinants of improved tomato seed varieties adoption. The estimation assumed mutual exclusiveness of the in the adoption of the tomato seeds varieties, the local or traditional seed variety "Techiman" is the least prioritized (bottom) and Pectomer (extreme) being the most prioritirised. Based on this, the Seed variety "Techiman" being the traditional variety (unimproved varieties) was used as the base category relative to the other verities (ITSV)

The econometric results of the determinants of farmers' adoption of tomato seed variety are presented in Table 6.3 and Table 6.4. The tables contain the coefficients and marginal effects of the parameters of the multinomial logit (MNL) model of ITSV adoption. While the coefficients shows as only the direction, the marginal effect represents the unit change in the dependent variable being in a particular category vis-a-vis the reference category when a corresponding independent variable changes by one unit. As a rule of thumb, the non-adoptors, that is those who cultivated traditional variety "Techiman" seed variety is chosen as the base or reference category. This identification procedure allowed for the determination of marginal effects for all the independent variables relating to the adoption of PSV, PRSV or both PSV/PRSV. According to the LR chi-squared test, the fitted MNL model is statistically significant at 1% significance level, signifying that at least one of the regression coefficients is not equal to zero. It also means that the model fits the data very well. The results show that; gender of a farmer, household income, access to credit, and farmer residency for both GSZ and FSTZ positively influence the adoption of PSV. Farmers' tertiary education, extension contact and perception about potential yield influence the adoption of PSV negatively. Further, the adoption of PRSV is positively affected by sex of the farmer, household size, primary occupation, household income, access to credit, membership in FBO and farmers residency in FSTZ significantly. Farmers' contact with extension officers and perception about potential yield negatively influence the adoption of PRSV. Both farmers in GSZ and FSTZ, sex, household size, household income, access to credit, perception about market availability and farmer residency are significant and positively influenced tomato farmers' adoption of both PSV/PRSV, while tertiary education and perception about potential yield are significant and negatively associated with the adoption of both PSV/PRSV.

Table 6.3: Multinomial Logit estimates of Determinants of adopted ITSV in the Selected Agro-Ecological Zones Region of Ghana

	Pectomech		Power roma		Pectomech/Power roma	
Variable	**Coef.**	**S.E.**	**Coef.**	**S.E.**	**Coef.**	**S.E.**
Sex of the Farmer	1.6642**	0.6526	1.6423***	0.6234	1.4406**	0.6675
Age of the Farmer	0.0081	0.0245	0.0088	0.0236	0.0173	0.0260
Household Size	0.1281	0.0818	0.1449*	0.0806	0.1497*	0.0812
Basic Education	-0.6672	0.6653	-0.1671	0.6440	-0.5065	0.7022
Secondary Education	-0.8498	0.9294	-0.4626	0.8865	-1.4067	1.0585
Tertiary Education	-1.7608*	0.9452	-0.8632	0.9284	-2.2723**	1.0838
Primary Occupation	0.8083	0.5899	1.0256*	0.5617	-0.2377	0.6252
Income	2.6060***	0.6213	3.3514***	0.5873	3.4152***	0.6983
Extension Contact	-1.0584*	0.5734	-1.0234*	0.5586	-0.8722	0.6423
Credit Access	1.6087**	0.6290	1.7201***	0.6532	1.3832*	0.7605
Membership in Insurance Policy	0.5514	1.7541	1.4389	1.7297	-0.1164	2.0121
Cropping Type	0.4795	0.6097	0.3126	0.5857	0.6298	0.6338
Membership in FBO	1.5477	0.9835	2.1377**	1.0684	-1.3003	1.1278
Potential Yield	-0.4433**	0.1948	-0.4156**	0.1760	-0.3933**	0.1869
Market Availability	0.2427	0.1760	0.1498	0.1662	0.3910**	0.1811
Seed Access	-0.1265	0.1534	-0.0915	0.1492	-0.1757	0.1638
Pest Resistance	-0.0598	0.1896	-0.0477	0.1876	-0.0388	0.1947
Early Maturity	-0.0233	0.2009	0.0074	0.1944	-0.0553	0.2093
Storage Ability	0.2012	0.1627	0.1484	0.1567	0.2042	0.1684
Resistance to Bad Weather	-0.0047	0.1167	0.0565	0.1142	0.0322	0.1158
GSZ	2.5765***	0.7193	0.4085	0.6689	3.4812***	0.8135
FTSZ	4.9943***	0.8972	3.4113***	0.8568	6.7293***	1.0172
Constant	-1.6121	1.5689	-0.4430	1.4500	-3.3503	1.6082
Model diagnosis						
Number of obs =	508.0					
Wald Chi^2 (66) =	218.21					
$Prob>chi^2$ =	0.0000					
Pseudo R^2 =	0.1708					

Legend: ***, **, and * indicate significance levels at 1%, 5%, and 10% respectively.

NB: *Baseline category is Non-adoptors ('Techiman' variety), sample size is (508) farmers selected from three Agro Ecological zones with (100) Bootstrapping*

Source: *Author's Estimations from Field Survey, 2020*

Sex of the farmer has a positive and significant influence on the adoption of improved tomato seed varieties, over the traditional variety (TMSV). The result indicates that male farmers are more likely to adopt improved tomato seed varieties compared to their female counterparts. The marginal effects of sex on the adoption of PSV, PRSV, or PSV/PRSV are 0.0358, 0.0352 and 0.0217, suggesting that the probability of male adopting PSV, PRSV, and PSV/PRSV will increase by 3.58%, 3.52% and 2.17% respectively over a female. The finding suggest male farmers are more likely to adopt improved tomato seed varieties compared to their female counterparts

Household size is also found to be positive and a significant factor for the adoption of PRSV and PSV/PRSV, over the traditional variety (TMSV). This result indicates that farmers with larger sizes of household are more likely to adopt PRSV and PSV/PRSV over the conventional variety (TMSV). The marginal effects of household size on the adoption of PRSV, and PSV/PRSV are 0.034 and 0.022, suggesting that the probability of adopting PRSV and PSV/PRSV increase by 3.4% and 2.2% respectively if household size is increased by one person. This finding is consistent with Danso-Abbeam *et al.* (2017) who found that larger household sizes increase the adoption of improved seed varieties.

Education (mainly tertiary education) is negative and significantly related to the adoption of improved tomato seed varieties, over the traditional variety TMSV. The marginal effects of tertiary education on the adoption of PSV and PSV/PRSV are -0.1425 and -0.1161, suggesting that the probability of adopting PSV and PSV/PRSV will decrease by 14.25% and 11.61% respectively, compared to non-educated farmers. This finding contradicts that of Danso-Abbeam *et al.* (2017) who revealed a positive and significant relationship between education and the adoption of improved seed varieties.

Total Income is significantly and positively related to the probability of adopting the improved tomato seed varieties (including PSV, PRSV, or PSV/PRSV) at 1% significance level, over the traditional variety (TMSV). The marginal effects of income on the adoption of both PSV, PRSV, or PSV/PRSV are 0.0865, 0.1884, and 0.0805, suggesting that the probability of adopting PSV, PRSV, and PSV/PRSV will increase by 8.65%, 18.84%, or 8.05% respectively if income is increased by one Ghana Cedi. This result suggests that high-income farmers have a higher preference for PSV, PRSV, or PSV/PRSV compared to the traditional variety (TMSV). The negative relationship between income and farmers' adoption of improved agricultural technology is in contrast to the findings of Iqbal *et al.* (2006), Kalinda *et al.* (2014) and Min *et al*. (2015) who reported that households with more wealth or assets were more likely to adopt improved technologies when compared with poorer households.

Furthermore, farmers whose primary occupation is tomato farming are more likely to adopt PRSV over the traditional variety (TMSV). The marginal effect 0.1552 of primary occupation on the adoption of PRSV is positive and statistically significant, implying that the probability of adoption of PRSV will increase by 15.52% if tomato production is the farmer's primary occupation.

Extension contact has a negative and statistically significant influence on the adoption of PSV and PRSV over TMSV. Practically, farmers who have access to extension services are about 2.49% and 1.54% less likely to adopt PSV and PRSV respectively, if other things remain unchanged. This result shows that the provision of extension services does not increase the adoption of improved seed varieties. The finding contradicts that of Danso-Abbeam *et al*. (2017) and Mahama *et al.* (2020) in Ghana and Chandio and Yuansheng (2018) in Pakistan, who found a positive and significant effect of extension contact on the adoption of improved technologies. As recently argued by Dinku and Beyene (2019), farmers who have contacts with extension agents are more likely to be exposed to updated information about the importance and application of improved technologies through counseling and field demonstrations, which in turn increases their adoption. However, the present study proves otherwise.

Another variable that appears to be influential in determining farmers' adoption of PRSV over TMSV is membership in an FBO. The marginal effect (0.1757) of membership in FBO on the adoption of PRSV is positive and statistically significant at 5% significance level, implying that the probability of adoption of PRSV will increase by 17.57% if a farmer joins an FBO. The result is in line with Baiyegunhi *et al.* (2019) who established that farmers in rural northern Nigeria who belong to farmer cooperative societies are more likely to be exposed to improved technologies. A similar result was also noted by Kalinda *et al.* (2014) in southern Zambia and Danso-Abbeam et al. (2017) and Abdulai *et al.* (2018) in the Northern Region of Ghana who reported that membership in FBO has a positive and significant effect on technology adoption.

Access to a ready market is also positive and significantly affects farmers' adoption of PSV/PRSV than adopting TMSV. This indicates that if a farmer has access to a ready market, the probability of adopting PSV/PRSV will increase at 5% significant level. The result shows that access to ready market is associated with an increase in the probability of PSV adoption by 2.92%. The finding is in agreement with that of Abdulai *et al.* (2018) in the Northern Region of Ghana who reported that farmers who have been contracted to produce for a ready market tend to adopt improved production technologies.

As expected, access to credit is a positive and significant factor in the adoption of improved tomato seed varieties, suggesting that farmers with access to credit are more likely to adopt PSV, PRSV, or PSV/PRSV over TMSV. The marginal effects of access to credit on the adoption of PSV, PRSV, or PSV/PRSV are 0.0001, 0.0521, and 0.0359 (showing that credit receivers are approximately 1.00%, 5.21%, and 3.59% more likely to adopt PSV, PRSV, or PSV/PRSV respectively, if other factors remain unchanged. The positive and significant effect of access to credit is plausible because credit serves as one way of removing financial constraints for the purchase of modern and relatively expensive technologies (Dinku & Beyene, 2019). The finding is in line with the results of Chandio & Yuansheng (2018) in Pakistan and Dinku & Beyene (2019) in Ethiopia but disagrees with Ogada et al. (2014) in Kenya and Mahama et al. (2020) in Ghana who found a negative and significant relationship between access to credit and technology adoption.

Farmer residency in FSTZ also has a positive and significant influence on the adoption of improved tomato seed varieties, over TMSV. The result indicates that farmers residing in FSTZ are more likely to adopt improved tomato seed varieties compared to those residing in CSZ. The marginal effects of farmer residency in FSTZ on the adoption of PSV, PRSV, or PSV/PRSV are 0.0489, 0.4360, and 0.4491, suggesting that the probability of adopting PSV, PRSV, or PSV/PRSV will increase by 4.89%, 43.60%, and 44.91% respectively compared to residing in CSZ.

Also, farmer residency in GSZ is positive and significantly correlated with the adoption of PSV or PSV/PRSV, over TMSV, suggesting that farmers residing in GSZ are more likely to adopt PSV or PSV/PRSV compared to those residing in CSZ. The marginal effects of farmer residency in GSZ showed the probability of adopting PSV and PSV/PRSV will increase by 26.03% and 28.77% respectively compared to those residing in CSZ.

Table 6.4: Marginal Effects of the Determinants of ITSV adoption

	Pectomech	Power Roma	Pectomech/Power Roma (Joint Adoption)
Variable	Marginal Effect	Marginal Effect	Marginal Effect
Sex of the Farmer	0.0358**	0.0352***	-0.0217**
Age of the Farmer	-0.0006	-0.0005	0.0013
Household Size	-0.0033	0.0034*	0.0022*
Basic Education	-0.0947	0.1056	-0.0177
Secondary Education	-0.0481	0.1222	-0.0908
Tertiary Education	-0.1425*	0.2189	-0.1161**
Primary Occupation	0.0615	0.1552*	-0.2037
Total Household Income	0.0865***	0.1884***	0.0805***
Extension Contact	-0.0249*	-0.0154*	0.0205
Credit Access	0.0001**	0.0521***	-0.0359*
Membership in Insurance Policy	-0.1260	0.2577	-0.1208
Cropping Type	0.0198	-0.0495	0.0366
Membership in FBO	0.0379	0.1757**	0.0712
Potential Yield	-0.0103**	-0.0004**	0.0037**
Market Availability	0.0072	-0.0327	0.0292**
Seed Access	-0.0033	0.0115	-0.0102
Pest Resistance	-0.0037	0.0009	0.0019
Early Maturity	-0.0031	0.0099	-0.0071
Storage Ability	0.0096	-0.0118	0.0051
Resistance to Bad Weather	0.0122	0.0122	0.0005
GSZ	0.2603***	-0.5210	0.2877***
FTSZ	0.0489***	-0.4360***	0.4491***

Legend: ***, **, and * indicate significance levels at 1%, 5%, and 10% respectively

Source: *Author's Estimations from Field Survey, 2020*

Perception about potential yield is also an important factor explaining the adoption of improved tomato seed variety. The result revealed a positive and statistically significant correlation between perception about potential yield and the adoption of PSV, PRSV, or PSV/PRSV at 5% significance level. This relationship suggests that farmers who perceived that improved variety improves yield are about 1.03%, 0.04%, and 0.37% more likely to adopt PSV, PRSV, or PSV/PRSV over TMSV.

The finding agrees with the results of Kaliba et al. (2000) who found that varietal characteristics such as yielding ability and disease tolerance are influential factors in determining farmers' adoption of improved technology.

6.4 Improved Tomato Seed Variety Adoption and Household Welfare

6.4.1 Multinomial Endogenous Switching Regression (MESR) Estimates

The average treatment effects of ITSV adoption on household welfare are estimated using the multinomial endogenous switching regression (MESR) model. The MESR model is examined simultaneously in two stages. The first stage models a the determinants of farmer's choice to adopt one of the two improved tomato seed varieties using the standard multinomial logit model while the second stage assessed the effect of the adoption of the improved ITSV on farmers wellbeing proxy on household income (HHI), household expenditure (HHE) and household assets (HHA), see Table 6.5. The MESR model is also estimated to correct for endogeneity bias, presuming that the multinomial dependent variable (ITSV adoption) is endogenous.

The selection terms (λ_0, λ_1, and λ_2) relating to the adoption of PRSV, PSV/PRSV and TMSV presented in Table 6.6a are significant at 5% and 10% levels, respectively, implying that there is the presence of endogeneity which is being corrected. This supports the use of the MESR model in estimating the data. The results reject the null hypothesis of no correlation between ITSV adoption and household welfare, suggesting a good fit of the MESR model and a positively correlated with tomato production. The Hausman test for IIA assumption also showed no systematic change in the coefficients if we excluded one of the outcomes from the model (see appendix 2 for the test result). The Chi-squared value for Power Roma and Pectomech/Power Roma excluding Pectomech in addition to the base outcome ("Techiman") were not significant, indicating that there is no evidence that the IIA assumption has been violated.

The results also indicate that gender of the farmer, income, credit access, perception about potential yield of ITSV, and farmer residency in FTSZ significantly influenced the welfare of the adoption of PSV, PRSV, or PSV/PRSV respectively. The factors that determine the welfare of the adoption of PSV were tertiary education, extension contact and farmer residency in GSZ. Whereas household size, primary occupation and extension contact, significantly influenced the welfare of adoption of the PRSV, household size, tertiary education, market availability, and farmer residency in GSZ significantly influenced the adoption of both PSV/PRSV. The determinants of ITSV adoption are corrected based on the MESR model. The instrumental variables were membership in FBO and membership in insurance policy respectively. These variables were used as instruments following literature, intuition and falsification test. According to the F-test (89.50), the instruments were valid, meaning that they meet both relevance and exogenous conditions. Intuitively, FBO is seen as a platform for adoption of improved agriculture technology, hence belonging to an FBO would have a direct relation with adoption but may have indirect relation with welfare. In the case of membership of insurance company, a farmer who has insured his or her product would feel secured and hence does not fear adopting a new technology, knowing in the event of failure he/she would be covered. On the contrary, insuring ones' farm is not a guarantee for a better life (welfare), thus it could be deduced that, insurance has a direct relation with adoption but has an indirect relation with welfare.

Table 6.5: Selectivity Correction Based on Multinomial Logit model estimates of Determinants of Welfare of the Selected Improved Tomato Seed Variety

	Pectomer		**PowerRoma**		**Pectomer/Power Roma**	
Variable	**Coef.**	**S.E.**	**Coef.**	**S.E.**	**Coef.**	**S.E.**
Sex of the Farmer	1.6642**	0.6526	1.6423***	0.6234	1.4406**	0.6675
Age of the Farmer	0.0081	0.0245	0.0088	0.0236	0.0173	0.0260
Household Size	0.1281	0.0818	0.1449*	0.0806	0.1497*	0.0812
Secondary Education	-0.8498	0.9294	-0.4626	0.8865	-1.4067	1.0585
Tertiary Education	-1.7608*	0.9452	-0.8632	0.9284	-2.2723**	1.0838
Primary Occupation	0.8083	0.5899	1.0256*	0.5617	-0.2377	0.6252
Total HH Income_	-2.6060***	0.6213	-3.3514***	0.5873	-3.4152***	0.6983
Extension Contact	-1.0584*	0.5734	-1.0234*	0.5586	-0.8722	0.6423
Credit Access	1.6087**	0.6290	1.7201***	0.6532	1.3832*	0.7605
Cropping Type	0.4795	0.6097	0.3126	0.5857	0.6298	0.6338
Potential Yield	-0.4433**	0.1948	-0.4156**	0.1760	-0.3933**	0.1869
Market Availability	0.2427	0.1760	0.1498	0.1662	0.3910**	0.1811
Seed Access	-0.1265	0.1534	-0.0915	0.1492	-0.1757	0.1638
Pest Resistance	-0.0598	0.1896	-0.0477	0.1876	-0.0388	0.1947
Early Maturity	-0.0233	0.2009	0.0074	0.1944	-0.0553	0.2093
Storage Ability	0.2012	0.1627	0.1484	0.1567	0.2042	0.1684
Resistance to Bad Weather	-0.0047	0.1167	0.0565	0.1142	0.0322	0.1158
GSZ	2.5765**	0.7193	0.4085	0.6689	3.4812***	0.8135
FTSZ	4.9943**	0.8972	3.4113***	0.8568	6.7293***	1.0172
Constant	-1.6121	1.5689	-0.4430	1.4500	-3.3503	1.6082
Hausman Test for IIA						
Power Roma	0.799	Fail to reject Ho				
Pectomech/Power Roma	0.389	Fail to reject Ho				
Test for Instrumental Variables	89.50***					
LR test for combining Alternatives						
0,2	41.85***					
0,3	39.165***					
0,1	49.595***					
2,3	55.658***					
2,1	57.222***					
3,2	46.746***					

Legend: ***, **, and * indicate significance levels at 1%, 5%, and 10**%** respectively

NB: Baseline category is Non Adoptors ('Techiman' seed variety), sample size is 508 farmers selected from three Agro Ecological zones with (100) Bootstrapping.

Source: Author's Estimations from Field Survey, 2020

6.4.2 Average ITSV Adoption Impacts on Household Welfare

Having examined the determinants of adoption, the study proceeds to assess the impact/effect of adoption on household welfare. The results of the average effects of improved tomato seed variety adoption on household welfare (including household income, household expenditure, and household assets) with correction for endogeneity bias are presented in Table 6.6(a and b). The dependent variables are log-transformed to minimize potential problems of heteroscedasticity. The table presents the average treatment effect on the treated (ATT) which indicates the average difference in household income if adopters had adopted relative to if they had not adopted. The results reveal that the adoption of TSV is significantly related to household income, household expenditure, and household assets. The adoption of PSV (and the joint adoption) has a positive effect on household income when compared to the Non-adopters (TMSV). However, the adoption of PRSV increases household expenditure and household asset rather than household income when compared to Non-adopters (TMSV). On the whole it is realized that, adoption of improved seed variety improves the general wellbeing of farmers as it increases their (assets, income and expenditure). Therefore, steps in ensuring adoption improved agricultural technology (seed variety) should be prioritized by government, NGOs and many other stakeholders.

Table 6.6(a): Average Improved Tomato Seed Adoption Impacts on Household Welfare

		Household Expenditure			Household Income			Household Assets		
Adoption decision	**Improved Seed Variety**	**PSV**	**PRSV**	**Joint Adoption**	**PSV**	**PRSV**	**Joint Adoption**	**PSV**	**PRSV**	**Joint Adoption**
Adoption	**A**	1690.788 (43.816)	2685.000 (288.130)	5848.311 (405.63)	1809.948 (37.520)	1694.660 (70.648)	6714.000 (512.31)	1632.034 (116.647)	2267.711 (204.453)	7340.000 (446.145)
If adopters had not adopted	**B**	1535.401 (55.512)	2267.711 (204.453)	5192.430 (393.110)	1730.362 (59.704)	1730.362 (59.704)	5565.000 (455.230)	1603.876 (72.040)	2113.194 (132.753)	5230.000 (395.161)
(diff (ATT) =A-B)	**C**	155.386*** (0.914)	418.889** (103.076)	655.881*** (162.31)	79.586*** (0.577)	-35.701*** (0.117)	1149*** (42.114)	28.158*** (0.023)	154.518** (0.921)	2110.0** (184.126)
Selective terms										
	λ_0		-0.465 (1.402)	1.075 (72.364)		1.249 (0.940)	0.263 (9.403)		2.949** (1.403)	-0.641 (4.954)
	λ_1	-0.7619 (1.345)		1.923 (89.301)	1.859*** (0.689)		0.479 (8.921)	1.525** (0.684)		-1.732 (6.344)
	λ_2	2.604 ** (1.389)	0.460 (1.517)		-0.635 (0.735)	-1.056 (1.010)		-0.447 (0.786)	-2.651* (1.606)	

Legend: ****, **, and * indicate significance levels at 1%, 5%, and 10% respectively*
NB: Standard Errors in parenthesis

Source: Author's Estimations from Field Survey, 2020

Table 6.6(b): Summary of Average ITSV Adoption Impacts on Household Welfare

	Household Welfare		
	Household Expenditure	Household Income	Household Asset
TSV Adoption	ATT	ATT	ATT
Pectomech	155.386*** (0.914)	79.586*** (0.577)	28.158*** (0.023)
Power Roma	418.889 (103.076)**	-35.701*** (0.117)	154.518*** (0.921)
Joint Adoption	655.881 (162.31)***	1149.000*** (42.114)	2110.000** (184.126)

Legend: ****, **, and * indicate significance levels at 1%, 5%, and 10% respectively.*

NB: Standard Errors in parenthesis

Source: Author's Estimations from Field Survey, 2020

6.4.3 Distribution of Household Welfare of ITSV Adoption

Figure 6.2 shows the impact of ITSV adoption on household income, household expenditure, and household assets using the kernel density distribution of predicted values by adoption status. The density is measured on a continuous scale. As displayed in the Figure, the kernel densities of predicted values of household income for adopters of PSV, PRSV, PSV/PRSV, and the Non-adoptors (TMSV) are significantly skewed to the left. This finding contradicts that of Khonje et al. (2018) who revealed that the income of adopters of various technologies is skewed to right. Similarly, the results in Figure 6.2 show that the kernel densities of predicted values of household expenditure and household assets for adopters of PSV, PRSV, PSV/PRSV, and Non-adoptors (TMSV) are extremely skewed to the left. The figure provides an effective way of showing the expenditure structure of farm households, in addition to the parametric estimates (the average treatment effects).

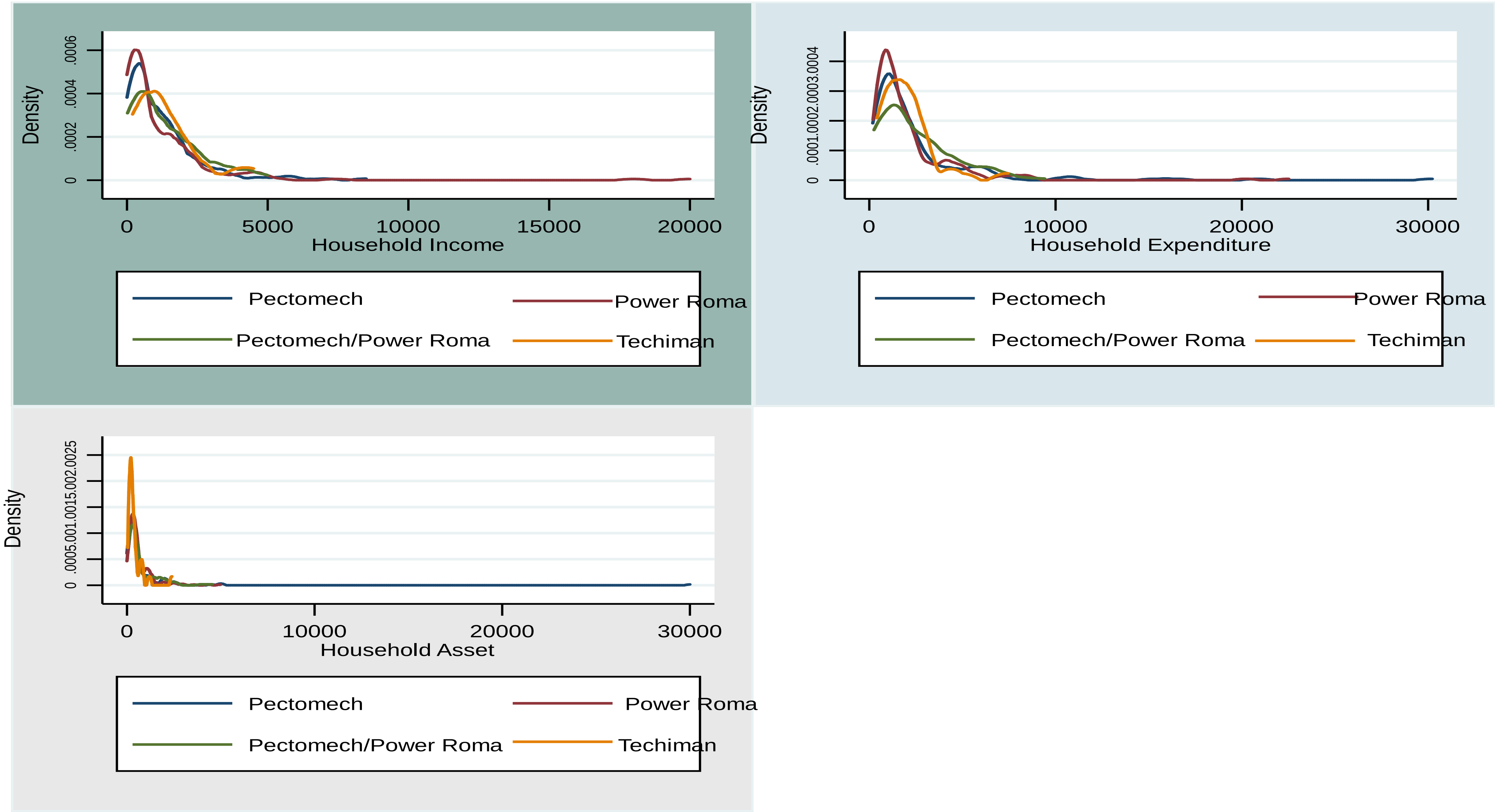

Figure 6.2: Kernel density distribution

Source: Author's Estimations from Field Survey, 2020

CHAPTER SEVEN

PRODUCTION AND MARKETING EFFICIENCY ANALYSES OF TOMATO FARMERS IN SELECTED AGRO-ECOLOGICAL ZONES IN GHANA

7.0 Introduction

This chapter discusses the results of the production efficiency, impact of adoption ITSV on efficiency and marketing efficiency of tomato farmers in selected agro-ecological zones in Ghana. The chapter is divided into two parts: the first part discusses the empirical results of metafrontier production estimates, inefficiencies of tomato farmers and the impact of adoption of ITSV on efficiency while the second part discusses the results of marketing margins, marketing efficiency of tomato farmers (and marketers) and the determinants of marketing in selected agro-ecological zones in Ghana. The results of the metafrontier production efficiency of tomato farmers relate to the tested hypotheses; the stochastic frontier estimates, determinants of technical efficiency; and the levels of technical efficiency while that of the impact of ITSV adoption on efficiency borders on the ATT, the selectivity terms and corrections for diagnostic terms. Regarding the marketing aspect, the results show that marketing channels and price flows in the tomato value chain; marketing cost, margins and efficiency of tomato farmers (and key market intermediaries including wholesalers and retailers); and the determinants of marketing efficiency of tomato farmers in the selected agro-ecological zones in Ghana.

7.1 Empirical Results of the Stochastic Production Frontier Model

7.1.1 Results of the Hypotheses Tested

For the use of the appropriate function form, the generalized likelihood ratio test was used. The likelihood-ratio statistic is equivalently distributed as a chi-square or the mixed chi-square (Coelli, 1995). The results of the generalized likelihood ratio (LR) chi-squared tests for determining the appropriate functional form, existence of inefficiency, and the effects of exogenous factors on technical inefficiency are presented in Table 7.1. The stochastic metafrontier model is estimated using the stochastic production frontier (SPF) estimates of the individual agro-ecological zones (GSZ, FSTZ, and CSZ). According to the table, the null hypothesis that the Cobb-Douglas production function is suitable for the data is rejected at 1% significance level. The transcendental (translog) functional form is used to represent the production structure, since the chi-square calculated values are greater than the chi-square critical values. Several recent studies (Owusu, 2019; Asravor et al., 2019; Wongnaa and Awunyo-Vitor, 2019) on the production efficiency of farmers also applied the translog SPF model to estimate technical efficiency. Besides the LR test, the translog production function is adopted because it is said to be flexible and imposes no restrictions on both production (demand) elasticities and elasticities of substitution, compared to the Cobb-Douglas production function which assumes constant returns-to-scale (Greene, 1993; Battese and Coelli, 1995). Also, the null hypothesis that technical inefficiency is absent is rejected at 1% significance level for each of the translog stochastic frontier production (SPF) models. This result generally indicates that the total variation in output or deviation of actual output from the frontier is in part, explained by farmers' inefficiencies (Belotti et al., 2013; Kidane and Ngeh, 2015). The presence of technical inefficiency in the data provides a strong justification for the use of the stochastic production frontier model, rather than the Ordinary Least Squares (OLS) or average production response model (APR). Unlike the stochastic production frontier model the (OLS and the APR) produces biased and inefficient estimates (Onumah et al., 2013 cited in Mabe, 2018).

Table 7.1: Hypotheses Tests for the use of Stochastic Frontier and Metafrontier Models

Null hypothesis	**(n)**	**Df**	**Chi-Square Test**		
Cobb-Douglas functional form is appropriate			$\chi^2 - Cal$	$\chi^2 - Crit$	$\rho - Values$
GSZ	250	21/49	114.54	34.39	0.000
FSTZ	158	21/49	43.62	34.39	0.0012
CSZ	100	21/49	40.11	34.39	0.0016
Metafrontier	508	21/49	230.37	34.39	0.0000
No inherent inefficiency					
GSZ	250	38/39	128.37	29.41	0.0000
FSTZ	158	38/39	58.76	29.41	0.0000
CSZ	100	38/39	53.95	29.41	0.0005
Metafrontier	508	38/49	117.54	29.41	0.0000
Homogeneous technologies					
There are no differences in technologies used in GSZ, FSTZ and CS	508	38/49	121.12	65.81	0.0002

Source: Author's Estimations from Field Survey, 2020

Furthermore, the null hypothesis that none of the exogenous explanatory factors have a significant effect on technical inefficiency is rejected at 1% significance level. Also, the stochastic metafrontier model is used to estimate technical efficiencies of tomato farmers in the three agro-ecological zones on the basis that farmers in each zone operate under different technologies (Aravindakshan et al., 2018). To justify the use of the stochastic metafrontier model, the LR chi-squared test is conducted to test the null hypothesis that tomato farmers in the three selected agro-ecological zones operate with similar or homogenous production technologies against the alternative hypothesis that tomato farmers in the three selected agro-ecological zones operate with heterogeneous production technologies. The results show that the null hypothesis is rejected at 1% significance level, confirming that tomato farmers in the three agro-ecological zones operate with different production technologies. However, by using the stochastic metafrontier model, all potential biases in technical efficiency due to differences in production technologies and capacity imposed by tomato seed variety have been corrected (Villano et al., 2010). The differences in production technologies across the zones are evident in the results since the translog SPF model for GSZ is nested into translog SPF models for FSTZ and CSZ, whereas at the same time, the translog SPF model for FSTZ is also nested into the translog SPF models for GSZ and CSZ respectively.

7.1.2 Group-Specific SPF Estimates

The results in Table 7.2 show the individual translog stochastic production frontier (SPF) estimates and the metafrontier estimates. The dependent variable, output, and the input variables are all mean-corrected to zero and log-transformed, which implies that the first-order coefficient estimates of the model represent the corresponding elasticities. This study interprets partial output elasticity as the percentage change in output as a result of a one-percent change in an input.

The table shows that the estimated returns-to-scale (RTS) is greater than one in GSZ (1.5111) but less than one in FSTZ (0.1194) and CSZ (-6.6092), indicating that farmers in GSZ are operating at increasing returns to scale (IRTS) while farmers in FSTZ and CSZ are operating at decreasing returns to scale (DRTS). The results suggest that by increasing all factor inputs by 1% in each zone, total tomato output in GSZ and FSTZ will increase by 1.5111% and 0.1194% respectively, but decreases in CSZ by 6.6092%.

The quantity of seed planted by farmers is significant and positive in the GSZ and FSTZ but negative in the CSZ. The partial elasticities of seed indicate that a one-percent increase in the quantity of seed planted by farmers will lead to 0.3840% and 0.1477% increase in tomato output in GSZ and FSTZ at 1% level respectively. In contrast, a 1% increase in the quantity of seed planted by farmers will result in a 0.4764% decrease in tomato output in CSZ at 10% level. The coefficient of land, labour, herbicides, and tractor services are also significant in GSZ. Land, herbicides, and tractor services are positive and significant at 1%, 10%, and 1% levels respectively, while labor is negative and significant at 1% level. The partial elasticities of land, herbicides, and tractor services suggest that a 1% increase in land, herbicides used, and value of tractor services will lead to 0.4979% and 0.1477%, 0.0712% and 0.0949% increase in tomato output in GSZ respectively. The partial elasticities of labour show that a 1% increase in labour will result in a 0.6396% decrease in tomato output in GSZ. The positive effect of land and seed agrees with Asravor et al. (2019) and Wongnaa and Awunyo-Vitor (2019) who reported a positive and significant effect of land and seed on rice and maize production in some selected agro-ecological zones in Ghana. However, the negative effect of labour in this study contradicts Asravor et al. (2019) but agrees with Owusu (2016) and Wongnaa and Awunyo-Vitor (2019). Owusu (2016) further found a negative effect of land on maize production in some selected agro-ecological zones in Ghana. The positive effect of land and seed on farmer output suggest that, land size and the use of the right quantity seed could improve or increase farmers output, thus it suggested for stakeholders in agriculture to help or provide farmers with the right training on land fertility and utilization and the quantity of seed to be used.

Table 7. 2: Maximum Likelihood Estimates of the New-Two Step Stochastic Metafrontier Translog Model

Variables	GSZ Model		FSTZ Model		CSZ Model		Metafrontier Model	
	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
lnLand	0.4979***	0.1623	-0.1269	0.2851	-0.3311	0.6931	0.4407***	0.0467
lnLabour	-0.6396***	0.0219	-0.0273	0.0741	-0.6299	0.7131	-0.0594***	0.111
lnFertilizer	0.1284	0.1197	0.0965	0.1040	-0.5287	0.5057	0.1089***	0.248
lnSeed	0.3840**	0.5060	0.1477**	0.0616	-0.4764*	6.4874	0.2731***	0.0731
lnHerbicide	0.0712*	0.0387	0.1095	0.6493	-0.9949	0.7429	0.0678***	0.0185
lnInsecticide	-0.0257	0.0403	-0.0925	0.8210	-0.8538	0.5700	-0.0439**	0.0206
lnTractor	0.0949***	0.0322	0.0124	0.1217	0.2056	0.1444	0.0868***	0.0154
$\ln Land^2$	0.1726	0.1931	0.2181	0.1738	0.0906	0.2206	0.2956***	0.0495
$\ln Labour^2$	0.0145	0.0226	0.0784	0.0752	0.1727	0.1222	0.0259***	0.0078
$\ln Fertizer^2$	-0.0533	0.0499	-0.0421	0.2663	-0.0844	0.1054	-0.0244*	0.0139
$\ln Seed^2$	0.0732	0.1715	0.0814	0.2675	-0.4432	0.0007	0.0089	0.0619
$\ln Herbicid^2$	0.0073	0.0726	0.1048	0.9760	-0.6352*	0.8491	0.0453	0.0387
$\ln Insecticide^2$	0.1213	0.0922	-0.2545	0.2279	-0.7336	0.7743	0.0884**	0.0437
$\ln Tractor^2$	0.0256***	0.0068	-0.0088	0.0237	0.0281	0.0246	0.0204***	0.0032
lnLand × Labour	0.2530**	0.0957	-0.0996	0.1873	0.0702	0.1728	-0.0536*	0.0297
lnLand × Fertilizer	0.1479*	0.0794	0.2710	0.1773	0.2465*	0.1455	0.1824***	0.0276
lnLand × Seed	-0.3893**	0.1546	0.0187	0.3322	-0.5451	0.5721	-0.0246	0.0611
lnLand × Herbicide	-0.0112	0.0889	-0.8811*	0.5311	0.1466	0.4816	-0.0308	0.0369
lnLand × Insecticide	-0.1336*	0.0773	0.0159*	0.5844	-0.6699	0.4558	-0.0421	0.0372
lnLand × Tractor	-0.0143	0.0141	-0.0105	0.0233	-0.0315	0.0333	-0.0067	0.0052
lnLabour × Fertilizer	-0.1252*	0.0727	0.0056	0.1719	-0.6516***	0.1538	-0.1007***	0.0204
lnLabour × Seed	-0.2856**	0.1323	0.2399	0.4762	-0.9347**	0.4428	-0.2482***	0.0506
lnLabour × Herbicide	-0.0115	0.0732	0.0098	0.4832	-0.0745	0.2363	-0.0115	0.0296

Table 7.2 continued

lnLabour×Insecticide	0.1478*	0.0874	-0.2419	0.4930	0.7013**	0.3004	0.1223***	0.0342
lnLabour×Tractor	-0.0019	0.0171	0.0405	0.0438	0.0798**	0.0298	0.0191***	0.0054
lnFertilizer×Seed	0.2735*	0.1553	0.4277	0.2863	-0.3029	0.3955	0.1076**	0.0498
lnFertilizer×Herbicide	-0.0279	0.0752	0.5146	0.4681	0.2584	0.2442	0.0509*	0.0295
lnFertilizer×Insecticide	-0.0784	0.0786	-0.5348	0.4681	-0.9198**	0.3369	0.0713**	0.0298
lnFertilizer×Tractor	0.0197	0.0132	-0.0396	0.0271	0.0006	0.0239	0.0069*	0.0036
lnSeed×Herbicide	-0.0376	0.1228	0.2308	0.5953	-0.4629	0.6514	0.0140	0.0539
lnSeed×Insecticide	0.1155	0.1411	-0.1960	0.9271	-0.9599*	0.1544	0.1175*	0.0604
lnSeed×Tractor	-0.0134	0.0108	0.0468	0.0379	-0.0306	0.0602	0.0157**	0.0068
lnHerbicide×Insecticide	-0.0772	0.0773	0.0711	0.1257	0.3766	0.3617	-0.0157	0.0357
InHerbicide×Tractor	0.0134	0.0108	0.0300	0.9517	0.0039	0.0345	-0.0233***	0.0042
InInsecticide×Tractor	-0.0065	0.0117	-0.0431	0.1111	0.0744	0.0538	0.0058	0.0045
Constant	-0.0327	0.2499	-0.5494	0.9459	-2.7645*	0.6365	0.0340	0.0872
RTS	1.5111		0.1194		-6.6092			
Log-Lik	139.7159		104.9329		74.4009		79.0894	
Wald $\chi^2(35)$	193.46***		67.60***		78.92***		795.22	

Legend: ****, **, and * indicate significance levels at 1%, 5%, and 10% respectively*

Source: Author's Estimations from Field Survey, 2020

7.1.3 Stochastic Metafrontier Estimates

From Table 7.2 above, land, fertilizer, seed, herbicide, and tractor services are positive and significant at 1% level, while labour and insecticide are negative and significant at 1% and 5% levels respectively. The results show that land has the largest positive (0.4407) impact in tomato production, followed by seed (0.2731), fertilizer (0.1089), tractor services (0.0868), and herbicide (0.0678). In contrast, labour has the largest negative (0.0594) impact on tomato production, compared to insecticide (0.0439). The partial elasticities of land, seed, fertilizer, tractor services, and herbicide indicate that a one-percent increase in the quantity of land, seed, fertilizer, tractor services, and herbicides used by farmers will lead to 0.4407%, 0.2731%, 0.1089%, 0.0868% and 0.0678% respectively while a 1% increase in the quantity of labour and insecticide will lead to 0.0594% and 0.0439% decrease in tomato output respectively. The positive effect of land, fertilizer, and seed is consistent with Dessale (2019) in Ethiopia and Oyetunde-Usman and Olagunju in Nigeria who found a positive and significant relationship between farm size and farm output.

7.1.4 Determinants of Group-specific Technical Inefficiency

The sources of technical inefficiency (TI) of tomato farmers in the various agro-ecological zones are presented in Table 7.3. TI is the reverse of technical efficiency (TE). This implies that factors that positively influence TI also reduce TE while factors that negatively influence TI also increase TE. The results reveal that the education of farmers, farming experience, membership in FBO, and access to extension services are found to be significant factors of TI of tomato farmers in GSZ. The coefficient of education is negative and significant at 1% significance level, suggesting that formal education reduces TI. This finding is consistent with Narala and Zala (2007), Cramon-Taubadel and Saldias (2014), in Chile and Ngango et al. (2019) in Rwanda, but contradicts the findings of Donkoh et al. (2013) and Anang et al. (2016) in Ghana who found a positive and significant effect of education on TI of small-scale maize farmers.

Membership in FBO also has significant and negative coefficient, indicating that belongint to a FBO reduces TI. The finding is consistent with Anang et al. (2016) and Wongnaa and Awunyo-Vitor (2019) in Ghana who found that farmers who belong to FBOs are more technically efficient than those who do not belong to FBOs. The results also found that access to extension services reduces TI in GSZ and FSTZ respectively. The finding is consistent with previous literature (Wongnaa and Awunyo-Vitor, 2019).

Contrary to expectation, highly experienced farmers are less efficient, compared to less-experienced farmers. The finding contradicts with Narala and Zala (2007) in Central Gujarat who found that highly-experienced farmers are more efficient than less-experienced farmers.

The coefficient of sex is significant and negatively related to TI in FSTZ, but positively correlated with TI in CSZ. The negative effect of sex on TI is consistent with Donkoh et al. (2013) and Anang et al. (2016) while the positive effect of sex on TI is in agreement with Wongnaa and Awunyo-Vitor (2019).

Furthermore, farmer's whose primary occupation is tomato farming are less technically efficient compared to those who engage in tomato production as their secondary occupation. This result is contrary to expectation.

Table 7. 3: Determinants of Technical Inefficiency across the Agro-Ecological Zones

Variables	GSZ Model		FSTZ Model		CSZ Model		Metafrontier Model	
	Coeff.	**SE**	**Coeff.**	**SE**	**Coeff.**	**SE**	**Coeff.**	**SE**
ln (σv^2)	-2.0953***	0.1844	-1.6448***	0.1291	-1.4744***	1.6193	-3.3802***	0.2192
Sex	-1.1111	0.6940	-2.4081**	1.0461	5.8368**	2.7453	0.0105	0.2377
Age	0.0275	0.0203	0.0790	0.0492	-0.1074	0.0741	-0.0081	0.0092
Education	-0.9169*	0.5256	2.8475	1.9228	1.5353	2.1419	0.3597*	0.2172
Household size	-0.5399	0.8289	3.6567	2.5807	-1.3413	2.8821	0.2720	0.4069
Marital status	-0.0874	0.0729	3.4863	4.2894	-2.2479	1.4213	0.0182	0.5953
Occupation	0.5019	0.4541	-3.7965	3.4559	3.3556*	2.0218	-0.0174	0.2349
Farming experience	0.3737**	0.1589	-0.0631	0.3389	-0.22750	0.6491	0.2291***	0.0658
Farming type	-0.0736	0.4264	-1.4818	1.0661	1.3671	1.3867	0.7663***	0.1994
Membership in FBO	-1.7440**	0.6522	2.0110	2.5760	-3.0353	5.1542	-0.6399	0.4170
Access to credit	0.4102	0.5427	0.4087	2.5760	-0.4888	4.7024	-0.1059	0.4031
Access to extension	-1.1916**	0.5127	-0.0633***	0.0188	2.8829	1.8977	-0.7404**	0.2753
Constant	-0.3929	1.4224	-5.2248	3.7797	-6.6865	5.7682	-2.0111**	0.7718

Legend: ***, **, and * indicate significance levels at 1%, 5%, and 10**%** respectively

Source: Author's Estimations from Field Survey, 2020

7.1.5 Determinants of Metafrontier Technical Inefficiency

This section of the study examines the determinants of technical efficiency across the three agro-ecological zones as required by objective three of the study. Assessment of this is important to the extent that it helps policy makers to formulate policies towards improving the efficiencies. Table 7.3 shows the result on the determinants of the metafrontier inefficiency and indicates that, education, farming experience, and farming type positively and significantly influence TI while access to extension negatively and significantly influences TI of tomato farmers in Ghana. The results show that the educated, highly-experienced farmers and farmers who practice mixed cropping are less technically efficient while farmers who have access to extension services are more technically efficient. The finding suggests that as farmers grow older or become educated, their technical inefficiencies increase. This is not consistent with our *a priori* expectation as highly-experienced and educated farmers have access to current information and the expertise to understand extension advice needed to improve production efficiency. The positive effect of extension on technical efficiency is consistent with expectation since extension agents provide information on improved production methods through demonstrations for farmers to understand and practice them.

7.1.6 Technical Efficiencies and Technology Gap Ratios of Tomato Farmers

The study further looked at the technology gap ratio (TGR) on farm metafrontier technical efficiency in addressing objective three of the study. The results of on-farm metafrontier technical efficiency (MFTE) and technology gap ratio (TGR) of tomato farmers are presented in Table 7.4. MFTE scores are calculated by taking the ratio of actual output to the frontier output. The mean MFTE of the stochastic metafrontier is 77.19%, with a minimum of 15.76% and a maximum of 96.47%. The MFTEs for farmers in the FSTZ range from 4.69%

to 100.00% with a mean of 98.17%. Also, MFTEs for tomato farmers in GSZ range from 23.49% to 99.61% with a mean of 77.44%. Whereas MFTEs for tomato farmers in the CSZ range from 17.29% to 99.99%, with an estimated mean of 86.51%. The findings imply that on average, tomato farmers in GSZ, FSTZ, and CSZ produce at 22.56%, 1.83%, and 13.49% below their respective frontiers. However, the MFTE scores indicate that farmers in FSTZ perform better than their colleagues in GSZ and CSZ. Also, a MFTE score of 100% is recorded among the farmers in FSTZ. In rice production, Mabe (2018) also reported that TE scores of rice farmers in GSZ and CSZ are lower when compared with MFTE scores of farmers in FSTZ. These findings could be attributed to the bimodal rainfall in FSTZ which gives room for all year-round farming, hence provide the farmers in FSTZ more income to explore new technology over their counterparts in GSZ and CSZ.

Table 7. 4: Summary Statistics of Metafrontier Technical Efficiencies and Technology Gap Ratios

Central Tendencies	GSZ		FSTZ		CSZ		Metafrontier	
	MFTE	TGR	MFTE	TGR	MFTE	TGR	MFTE	TGR
Mean	0.7744	0.8689	0.9817	0.7526	0.8651	0.7605	0.7719	0.8114
St. Deviation	0.1731	0.1167	0.0939	0.1845	0.1729	0.1851	0.1446	0.1648
Minimum	0.2349	0.5333	0.0469	0.1576	0.2298	0.3777	0.1559	0.1576
Maximum	0.9961	1.5217	1.0000	1.0445	0.9999	1.4654	0.9647	1.5217
Sample Size	250		158		100		508	

Source: Author's Estimations from Field Survey, 2020

TGR is estimated to show the productivity potential and gap between each agro-ecological zone frontier and the metafrontier given that all farmers in any of the agro-ecological zone have the potential access to the best available technology for tomato production. TGR of 1 implies that each group-specific frontier is tangential to the metafrontier whereas TGR implies that each group-specific frontier is not tangential to the metafrontier. TGR> 1 indicates better returns from technology. The results in Table 7.4 reveal a mean TGR of 81.14% (16.48), ranging from 37.77% to 146.54%. This indicates that on average, tomato farmers in Ghana achieve 81.14% of the potential output given the technology available to overall tomato production. The mean TGR for farmers in GSZ is 86.89% (11.69), ranging from 53.33% to 152.17%. The mean TGR for farmers in FSTZ is 75.26% (18.45) with a minimum of 15.76% and a maximum of 104.45% whereas TGR for farmers in CSZ is on average 76.05% (18.51), ranging from 37.77% to 146.54% respectively. The figures in the parentheses are standard deviations that show the potential variations in TGR due to the lack of full use of the technologies available for tomato production. The findings imply that, on average, about 13.11%, 24.74% and 23.95% of the TGRs in GSZ, FSTZ, and CSZ are farther below the meta-frontier. This finding could be attributed to limited usage of the available technology for tomato production and external shocks such as poor environmental conditions that affect farmers' productivity.

7.1.7 Levels and Distributions of Group-specific Technical Efficiencies

Table 7.5 presents the scores and distribution of technical efficiency (TE) of tomato farmers in the three agro-ecological zones. The table contains the minimum, maximum, and the mean TE as well as the frequencies and percentages of the different categorization of TE scores. The results reveal that TE for farmers in GSZ ranges from 31.01% to 99.12% with a mean of 77.44%. The mean TE of FSTZ farmers is 98.17%, ranging from 51.30% to 100.00%. Also, TE of CSZ farmers ranges from 21.13% to 99.00%, with a mean of 86.51%. Except for GSZ where one farmer attained TE lower than 10%, none of the farmers in the FSTZ and CSZ had TE below 10%. A higher number of GSZ (41.60%), FSTZ (31.01%), and CSZ farmers

(46.00%) attained TE of 91-100%. From the results, about 89.60%, 92.40%, and 97.00% of farmers had TE scores of more than 50% in GSZ, FSTZ, and CSZ. The results indicate that on average, about 22.56%. 1.83% and 13.49% of tomato output are lost in the production process due to technical inefficiencies.

Table 7. 5: Levels and Distributions of Group-Specific Technical Efficiencies

Technical Efficiency Scores	GSZ		FSTZ		CSZ	
	Freq.	%	Freq.	%	Freq.	%
≤0.1	1	0.40	0	0.00	0	0.00
0.11-0.20	1	0.40	1	0.63	0	0.00
0.21-0.30	5	2.00	2	1.27	1	1.00
0.31-0.40	8	3.20	6	3.79	1	1.00
0.41-0.50	11	4.40	3	1.89	1	1.00
0.51-0.60	20	8.00	11	6.96	2	2.00
0.61-0.70	12	4.80	21	13.29	11	11.00
0.71-0.80	23	9.20	27	17.09	15	15.00
0.81-0.90	65	26.00	38	24.05	23	23.00
0.91-100	104	41.60	49	31.01	46	46.00
Total	**250**	**100**	**158**	**100.00**	**100**	**100.00**
	Min	0.3101	Min	0.5130	Min	0.2113
	Max	0.9912	Max	1.0000	Max	0.9900
	Mean	**0.7744**	**Mean**	**0.9817**	**Mean**	**0.8651**

Source: Author's Estimations from Field Survey, 2020

7.1.8. Estimates of the New-Two Step Stochastic Metafrontier Translog Model of ITSV

Table 7.6a shows the result of maximum likelihood estimates of the new-two step stochastic metafrontier translog model of the interaction between the conversional inputs and the adoption of the improved tomato seed varieties. The dependent variable (output) with its correspondents input variables were all log-transformed and mean-corrected to zero. Thus implies the first-order coefficient estimates of the model represent the corresponding elasticity' and gives room for the interpretation of the result as partial output elasticities. The coefficients are interpreted as the percentage change in output as a result of a one-percent change in an input.

For the adoption of the ITSV (PSV, PRSV and the joint adoption) inputs such as; the Land-size, fertilizer application, tractor services, quantity of seed planted by farmers, application of insecticides and herbicides are found to be statistically significant at various levels and positive, implying that for farmers who adopted any of the two ITSV or jointly adopted the two ITSV, a one -percentage increase in any of the above inputs leads to an increase in tomato output by more than one-percent. On the other hand, for the adoption of any of the ITSV or the joint adoption, the partial elasticities of labour shows that a 1% increase in labour will result in a decrease in tomato output. The positive effect of land and seed agrees with Geffersa et al. (2019) and Awunyo-Vitor (2019) who reported a positive and significant effect of land and seed on and maize and rice production in Ethiopia and Ghana but disagrees with the findings of Abro et al. (2014). The negative effect of labour also disagrees with the findings of Asravor et al. (2019) but agrees with Owusu (2016) and Wongnaa and Awunyo-Vitor (2019). The positive effects of land, fertilizer application, insecticides and herbicides application, and the quantity of seed used by a farmer on output, suggests that farmers if given the right training and credit facilities to own this inputs could help improve upon their output.

It is worth knowing that, the result of the maximum likelihood estimation of metafrontier in both the case of adoption of ITSV and the agro-ecological zones are similer. In both estimations, inputs such as landsize, seed, fertilizer, insecticides and pesticides are found to be statistically significants at various levels and positive for incresease in output while labour on the other hand is found to be significant but negative, thus reduces output. Deductively, it can be said, the agro-ecological zones operate in different environmental conditions and hence farmers adopt ITSV based on the environment and the heterogeneous nature of the ITSV.

Table 7.6 a: Estimates of the New-Two Step Stochastic Metafrontier Translog Model of ITSV

Variables	PSV		PRSV		Both PSV/PRSV		Metafrontier Model	
	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
lnLand	0.1819***	0.1275	0.2318	1.8054	0.2022***	0.0462	-0.0599	0.2164
lnLabour	-0.0118	0.0608	-0.1283*	0.0658	-0.0703***	0.0153	-0.0676**	0.0304
lnFertilizer	0.2549*	0.1501	0.0128	0.0933	0.0496	0.0320	0.2428	0.1879
lnSeed	0.2021	1.3977	0.1714**	0.0632	0.0334	0.0363	0.8298	0.7929
lnHerbicide	0.0437	0.0621	0.3269***	0.0979	0.0913***	0.0224	-0.1716	0.1553
lnInsecticide	0.0852	0.0658	-0.0849	0.1314	-0.0426	0.0301	0.0647	0.1753
lnTractor	0.0247	0.0618	0.0068	0.0566	0.0556**	0.0203	-0.0357	0.0682
$lnLand^2$	0.1896	0.1271	-0.3529*	0.1852	0.0617	0.0409	-0.0125	0.1775
$lnLabour^2$	0.0086	0.0311	-0.0077	0.0371	0.0393***	0.009	-0.1019**	0.3767
$lnFertizer^2$	0.2539**	0.1263	-0.1186	0.0601	0.0204*	0.0171	0.1892	0.1925
$lnSeed^2$	0.1168	0.2069	-0.2406	0.2127	-0.0665	0.0650	0.1412	0.2480
$lnHerbicid^2$	0.0563	-0.1998	-0.1648	0.1309	-0.0242	0.0427	0.2698	0.1654
$lnInsecticide^2$	0.0827	0.2047	-0.0779	0.2154	0.0291	0.0506	0.5077**	0.2366
$lnTractor^2$	0.0002**	0.1229	0.0037	0.0112	0.0140***	0.0042	-0.0114	0.0144
lnLand×Labour	0.3222	0.0888	0.1411	0.1309	-0.0006	0.0330	-0.1653	0.1437
lnLand×Fertilizer	0.0808*	0.0931	0.2376	0.1453	0.2277***	0.0300	0.1859*	0.0974
lnLand×Seed	-0.0499	0.1546	-0.2007*	0.1635	-0.1000	0.0629	-0.0497	0.2533
lnLand×Herbicide	0.0402	0.1369	-0.0718	0.1529	-0.0569	0.0429	0.3438**	0.1400
lnLand×Insecticide	0.0767*	0.1448	-0.2375	0.1773	0.0106	0.0471	0.3469*	0.1909

Table 7.6 a continued.

lnLand×Tractor	-0.0099	0.0179	-0.0059	0.0193	-0.0023	0.0056	-0.0086	0.0163
lnLabour×Fertilizer	0.1333**	0.0787	-0.1429	0.0875	-0.1061***	0.0236	0.0467	0.0935
lnLabour×Seed	-0.3844**	0.2057	-0.4564	0.2453	-0.2029***	0.0622	0.2488	0.3594
lnLabour×Herbicide	0.0216	0.1053	0.0024	0.1357	0.0201	0.0341	0.0182	0.1111
lnLabour×Insecticide	0.0471*	0.1141	0.0922	0.1632	0.0300	0.0400	-0.1613	0.1203
lnLabour×Tractor	0.0111	0.0161	0.0049	0.0213	0.0120*	0.0061	0.0224	0.2475
lnFertilizer×Seed	0.2025	0.2258	0.2233	0.1855	0.0122*	0.0611	0.0464	0.2865
lnFertilizer×Herbicide	0.2499**	0.1264	0.0882	0.1325	0.0200	0.0375	-0.3007**	0.1110
lnFertilizer×Insecticide	0.1641	0.1349	0.0400	0.1166	-0.0074	0.0300	0.1764	0.1434
lnFertilizer×Tractor	0.0082	0.0151	-0.0144	0.0122	0.0064	0.0044	0.0374*	0.0221
lnSeed×Herbicide	0.3119	0.2126	0.3748*	0.2120	0.1065*	0.0509	-0.2949	0.2323
lnSeed×Insecticide	0.1716	0.2308	0.2803	0.2264	0.0678	0.0600	0.0562	0.3086
lnSeed×Tractor	0.0451*	0.0255	0.0144	0.0255	0.0138*	0.0076	0.0409	0.0277
lnHerbicide×Insecticide	0.0596	0.1150	-0.0195	0.1598	-0.0762*	0.0422	-0.5283***	0.1748
InHerbicide×Tractor	0.0306*	0.0153	-0.0106	0.0192	-0.0248***	0.0040	-0.0274*	0.0159
InInsecticide×Tractor	0.0034	0.0179	-0.0123	0.0216	-0.0100	0.0056	0.0189	0.0176
Constant	-0.0248	0.3715	0.0156	0.3933	-0.3021**	0.1117	-0.9149**	0.4261
RTS	1.5644		0.3146		1.1439			
Log-Lik	175.89		112.03		146.60		43.32	
Wald $\chi^2(35)$	85.31***		125.84***		537.27***		103.23***	

Legend: ****, **, and * indicate significance levels at 1%, 5%, and 10% respectively*

Source: Author's Estimations from Field Survey, 2020

7.1.8.1 Effect of ITSV adoption on production efficiency of tomato farmers

Table 7.6b shows the result of the effect of adoption of (ITSV) on farmers' production efficiency. It contains the sample statistics (ATT estimates) of efficiency scores for the three tomato seed varieties. In all the estimations, the translog production frontiers fit the data reasonably well (based on the likelihood ratio tests), with statistically significant variables. The likelihood ratio (LR) chi-squared test conducted also rejects the null hypothesis that tomato farmers in the three selected agro-ecological zones operate with similar or homogenous production technologies. In contrast, the study rejects the null hypothesis that tomato farmers in the three selected agro-ecological zones operate with homogeneous production technologies. The results also imply that the use of the SMF model helped to correct for all potential biases in technical efficiency due to differences in tomato seed variety adoption. The SMF model was used to estimate technical efficiencies for ITSV adoption based on the notion that the varieties have varying levels of yield potency or effect due to specific characteristics.

Furthermore, ATT of tomato seed adoption on farmers' TE was estimated using the PSM technique. Accounting for potential selection bias of the adoption variable, the results showed that the group-specific TE scores increased with the adoption of improved tomato seed varieties. Thus, adopters of improved tomato seed variables seem to be more technically efficient compared to the adopters of the local variety. However, with the exception of power roma adoption, when compared with the traditional variety, adopters of pectomer and both pectomer and power roma would have achieved a lower TE if they had not adopted the improved varieties. For example, farmers who adopted pectomer and both pectomer and power roma, had mean TE of 93.1% and 90.9% respectively, compared to 86.2% and 88.8%, had they not adopted. In other words, farmers who adopted pectomech and both pectomer and power roma would have become 6.9% and 2.1% less efficient had they not adopted. Likewise, under the counterfactual conditions that adopters of power roma and the local variety had not adopted, they would have gained a higher TE if they had adopted the other improved varieties. The highest TE was achieved through the adoption of pectomer. This result is in line with that of Anang et al. (2020) who found that the adoption of improved maize variety increases TE in smallholder maize production in Ghana. In Nigeria, Obayelu et al. (2016) found that the adoption of improved protein maize increased TE of smallholder farmers. Ahmed et al. (2017) also revealed that farmers in Ethiopia who adopted improved maize varieties attained higher TE (82.34%), compared with their non-adopter counterparts (79.54%). Geffersa et al. (2019) also found that farmers using improved varieties attained a mean TE of 67.87%, while farmers using local maize variety attained a mean TE of 64.53%.

Table 7.6b: Impact of ITSV adoption on production efficiency of tomato farmers

	Mean Technical Efficiency Scores				
Adoption decision	**Seed Variety**	**Local variety**	**PSV**	**PRSV**	**Joint Adoption**
Adopting the technology	**A**	0.818	0.931	0.820	0.909
Not adopting the technology	**B**	0.910	0.862	0.914	0.888
(diff (ATT) =A-B)	**C**	-0.093*** (0.060)	0.069*** (0.012)	-0.095*** (0.014)	0.021* (0.013)

Legend: ****, **, and * indicate significance levels at 1%, 5%, and 10% respectively*
NB: Standard Errors in parenthesis
Source: Author's Estimations from Field Survey, 2020

7.2 Marketing Efficiency of Tomato Farmers and Market Intermediaries

Objective five of the study was aimed at determining the marketing efficiency and the determinants of marketing efficiency of actors or agents in the tomato market chain. This was obtained by the study identifying the actors, marketing channels, tomato prices, marketing margins, in the various agro-ecological zones among others.

7.2.1 Tomato Buying and price determination agents

Further analyses of the distribution of the tomato value chain actors (buyers) are presented in Table 7.7a and 7.7 b. These tables present the frequencies and percentages of tomato buyers and price determination agents in the tomato value chain. The results reveal that 18.80%, 41.20%, and 40% of the tomato buyers sampled were final consumers, retailers and wholesalers. Also, the number of wholesalers and retailers sampled in GSZ, FSTZ, and CSZ was more than consumers. Regarding price determination, farmers were asked who among the market actors determine the price of a crate (72kg) of tomatoes. From the farmer's response, it was revealed that the wholesalers display greater power on pricing (46.7%) compared to retailers (22.8%) and consumers (30.5%) across the three agro-ecological zones. Wholesalers had the greatest ability to reduce or raise prices of tomato because they often exercise monopolistic power in the market. Entry to the tomato wholesale market is somehow restricted and less competitive. This oligopolistic power in procurement reduces prices to producers below the level that would prevail under perfect competition. Sexton et al. (2005) affirmed that market intermediaries including wholesalers and retailers exploit peasant farmers to mark-up prices above the marginal cost, especially when it comes to perishable commodities as these products have inelastic supply. Wholesalers and retailers may lower prices to producers but increase prices to consumers as a reward to minimize the risk of postharvest losses and high marketing costs (Haung et al., 2006).

Table 7.7 (a): Summary Statistics of Tomato Actors (Buyers)

Tomato Buyers	**GSZ**		**FSTZ**		**CSZ**		**Pooled**	
	Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
Consumers	5.	14.20	5	20	5.00	25.00	15	18.80
Retailers	15	42.90	8	32	10.00	50.00	33	41.20
Wholesalers (Market Queen)	15	42.90	12	48	5.00	25.00	32	40.00
Total	35	100	25	100	20	100	80	100

Source: Author's Estimations from Field Survey, 2020

Table 7.7 (b): Tomato Price determination Agents

Tomato Actors	GZS		FSTZ		CSZ (100)		Pooled	
	Freq.	%	Freq	%	Freq	%	Freq.	%
Consumers	60	24.0	45	28.5	50	50.0	155	30.5
Retailers	71	28.4	37	23.4	8	8.0	116	22.8
Wholesalers (Market Queen)	119	47.6	76	48.1	42	42.0	237	46.7
Total	250	100	158	100	100	100	508	100

Source: Author's Estimations from Field Survey, 2020

7.2.2 Price Flows in the Tomato Value Chain

Prices of tomato are determined based on direct negotiations between the traders (buyers) and farmers. Besides the uncertainties of demand and supply in the market, prices of tomato may vary according to the season of production and distance that separates the place of production and the place of sale (Piya, 2001; Adepetu, 2010). In Ghana, for example, the FTSZ and CSZ experience two rainy seasons while the GSZ experiences only one rainy season. However, tomato production is usually highest in GSZ, especially in the wet season compared to the FTSZ and CSZ, suggesting that tomato production in GSZ may have a two-sided influence on the supply and prices of tomato in the FTSZ and CSZ. Given this, the study compares the prices of tomato received by various market players in selected agro-ecological zones in Ghana. The prices of tomatoes were collected on a per box/crate basis. A crate weighs about 72 kg on average. The average prices per 72kg of fresh tomato paid to and received by farmers and market intermediaries including wholesalers (who are mostly market queens) and retailers/tomato marketers association are presented in Table 7.8. From the table, the average price at which a farmer sells 72kg of fresh tomato was estimated to be GH¢129.4 whereas retailers and wholesalers sell the acquired item at GH¢298.4/72kg and GH¢234.8/72kg respectively. The increase in wholesale and retail prices can be due to the higher marketing costs (see Table 6.8 for reference) and overexploitation of consumers, especially in the cities. The finding corroborates Boateng et al.'s (2016) finding that the mean selling price of vegetables received by retailers was the highest when compared to the average selling price of vegetables received by wholesalers and producers.

The results also showed that farmers in the CSZ have a higher selling price (GH¢250.00/72kg) when compared to those in the GSZ (GH¢180.00/72/kg) and FSTZ (GH¢160.00/72kg). Similarly, wholesalers in the CSZ received a higher price (GH¢450.00/72kg) when compared to their counterparts in GSZ (GH¢370/72kg) and FSTZ (GH¢341/72kg). A similar trend was observed at the retail level. Retailers in the CSZ sell their tomato at a higher price (GH¢550/72kg) when compared to their counterparts in the GSZ (GH¢420/72kg) and FSTZ (GH¢380/72kg). For wholesalers and retailers, prices of tomatoes could reach as high as GH¢490/72kg and GH¢720/72kg respectively in the CSZ, whereas for farmers, prices of tomatoes could reach as low as GH¢120/72kg in the FSTZ. Price of tomatoes is higher in CSZ compared to FSTZ and GSZ. This high price of tomatoes in the CSZ could be attributed to higher demand of tomatoes in the CSZ which is partly due to higher population and the urban nature of the zone. Again, it could be attributed to highly irrigational nature of the zone which makes cost of production high and the catalyst on cost of sales compared to the other zones who are mostly into rainfed production.

Table 7. 8: Tomato Prices in Crates (72kg)

Variables	GSZ (30)			FSTZ (20)			CSZ (15)			Pooled (65)		
Tomato Actors	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**
Farmer/Self	180	150	200	160	120	195	250	200	350	183.3	156.7	248.3
Wholesalers/ Market Queens	370	245	425	341	230	400	455	420	490	388.7	298.3	438.3
Retailers/TMA	420	370	450	380	350	420	600	550	720	450.0	440.0	530.0

Source: Modified from Ghana Food Pricing, Dec, 2019.

7.2.3 Marketing Costs, Margins, and Efficiency of Tomato Value Chain Actors

Table 7.9 shows the descriptive statistics of marketing costs, margins, and efficiency per 72kg of fresh tomato earned by farmers, wholesalers, and retailers in the three agro-ecological zones. This table presents the means of the selected indicators. The marketing cost for farmers, wholesalers, and traders is recorded as variable costs including expenses on transportation, loading and off-loading, duties/taxes, and others (including paying fees for an undisclosed reason). The results revealed that on average, retailers had the highest gross margin (GH¢231.6 per 72kg of fresh tomato), followed by wholesalers (GH¢203.5 per 72kg of fresh tomato) and farmers (GH¢118.9 per 72kg of fresh tomato). This finding is partly because the retailers received fairly high revenues (GH¢530.0) per 72kg of fresh tomato than the wholesalers (GH¢438.3) and farmers (GH¢248.3) respectively. The finding is consistent with Toure and Wang (2013) in Bamako, Republic of Mali who found that the price of tomato at the farm gate is less than the retail price.

The mean marketing cost was also estimated to be GH¢30.00, GH¢ 65.00, and GH¢42.00 per 72kg of fresh tomato for the farmers, wholesalers, and retailers respectively. This finding is consistent with Boateng *et al.* (2016) who reported that wholesalers incurred higher marketing costs than retailers because the former incurs a higher transportation cost compared to the latter. According to Boateng et al. (2016), wholesalers tend to incur a higher marketing cost (and in particular transportation cost) because they assemble the product from different production areas before transporting them to the market, as compared to retailers who buy from wholesalers and resell usually on the same spot or a nearby market. Further analyses on the cost items revealed that, compared with duties/taxes, loading, and off-loading charges and other marketing charges, transportation and storage together accounted for more than 70% of total marketing costs incurred by farmers and wholesalers and 60% of total marketing costs incurred by retailers. Similarly, Iddi et al. (2017) reported that among levies, loading and off-loading charges, and other marketing expenses, transportation cost forms the highest part of total marketing cost of yam farmers, wholesalers, and retailers in Northern Region of Ghana.

Table 7.9: Annual Gross and Net margins of Tomato Key Players

Items	Farmers		Wholesalers		Retailers	
Marketing Margins	**Mean (GH¢)**		**Mean (GH¢)**		**Mean (GH¢)**	
a. Goss Revenue/72kg	248.3		438.3		530.0	
b. Cost of product/72kg	129.4		234.8		298.4	
c. Gross Margin/72kg (a-b)	**118.9**		**203.5**		**231.6**	
Marketing Costs (Expenses)		**% of Total Cost**		**% of Total Cost**		**% of Total Cost**
Transportation cost/72kg	15.0	50.00	35	53.85	10	23.81
Loading/offloading/72kg	3.0	10.00	5	7.69	5	11.90
Tax/duties/72kg	1.0	3.33	3	4.62	2	4.76
Storage cost/72kg	7.0	23.33	12	18.46	15	35.71
Other costs/72kg	5.0	16.67	10	15.38	10	23.81
d. Total Marketing cost/72kg	**30**	100.00	**65**	100.00	**42**	100.00
e. Net Margin/72kg (c-d)	**88.90**		**138.5**		**189.6**	

Source: Author's Estimations from Field Survey, 2020

Net margin was evaluated as gross margins (sales receipts) minus the marketing cost. As shown in Table 7.9, net margin per 72kg of fresh tomato was averaged at GH¢138.8, with a mean gross revenue of GH¢184.7 and an average marketing cost of GH¢45.7. However, the results suggest that profit earned by retailers and wholesalers was about twice that of farmers. The mean net margin per 72kg of fresh tomato was estimated at

GH¢189.0 and GH¢138.5 for retailers and wholesalers compared to GH¢88.9 for farmers. The results, on the other hand, suggest that retailers and wholesalers earn very high gross margins but incurring relatively low marketing costs compared to the farmers. In general, tomato marketing was found to be a profitable venture in the study area, as about18-25% of gross marketing margin was spent as marketing costs, with the remaining amount retained as net marketing margin. The finding agrees with Adesina et al. (2008) and Obayelu et al. (2014) who reported that marketing of fresh tomato, especially for retailers and wholesalers is more profitable in Nigeria. However, it disagrees with Wongnaa et al. (2014) who found that wholesalers have a higher marketing margin compared to retailers. The results in Table 7.10 further showed a mean marketing efficiency of 304.0%, indicating that tomato value chain actors make super-normal profits. The results also suggest that tomato value chain actors may increase profits by not merely minimizing cost, but also reducing postharvest losses. Comparatively, retailers were found to be the most efficient tomato value chain actors with a mean marketing efficiency of 450% (which is far over the break-even point), compared to farmers and wholesalers who on average, make a surplus of 296.33% and 213.08% respectively. The figures imply that tomato farmers and market intermediaries are highly efficient in the marketing of tomato. The finding agrees with Mandal et al. (2011) in West Bengal but disagrees with the findings of Iddi *et al.* (2017) in the Northern Region of Ghana who found that farmers are more efficient when it comes to yam marketing when compared to wholesalers and retailers.

Table 7.10: Marketing Efficiency of Key Actors

Items	Pooled	Farmers	Wholesalers	Retailers
	Average (GH¢)	Average (GH¢)	Average (GH¢)	Average (GH¢)
Gross Margin/72kg (c)	184.70	118.90	203.50	231.60
Marketing Cost/72kg (d)	45.70	30.00	65.00	42.00
Net Margin/72kg (e)	138.80	88.90	138.50	189.00
Marketing Efficiency/72kg (e/d)	3.04	2.963	2.131	4.50
Marketing Efficiency/72kg (%)	304.0	296.3	213.08	450.00

NB*: The unit of measurement for the tomatoes' is a crate for a (72kg)*

Source: Author's Estimations from Field Survey, 2020

7.2.4 Determinants of Marketing Efficiency of Tomato Farmers in Ghana

The OLS regression model was estimated to reveal the factors influencing the marketing efficiency (ME) of tomato farmers in Ghana. The OLS is used only when the Gauss Markov assumptions are binding. The assumption of model, the error term and the independent variable (see page 129). The Ramsey Regression Specification Error Test (RESET) was also used in testing for omitted variables and correct functional form specification (See appendix 2). It was found that there were no issues of omitted variables and also the right functional form was employed, since gamma $(\hat{Y} = 0)$. Though the marketing efficiency of players in the tomato value chain was computed as a ratio of net marketing margin (NMM) to total marketing cost (TMC), it has scores of more than 1% and approaches positive infinity. This makes the OLS superior to the fractional regression model in estimating the determinants of ME; fractional regression is appropriate when the dependent variable consists of values between 0 and 1. A 100% ME shows a perfect efficient market. However, if ME is greater than 100%, it indicates that tomato farmers make abnormal profits. Also, if ME is less than 100%, it means that the market is inefficient. The coefficients (marginal effect estimates) and the p-values corresponding are presented in Table 7.11. The F-statistic (48.310) was significant at 1% level, implying that at least one of the explanatory variables has a significant relationship with the ME of tomato farmers in Ghana. The R-squared is 0.874, indicating that about 87.4% of the total variation in the ME of tomato farmers was explained by changes in all the explanatory variables. The results further revealed that seven explanatory variables, education, experience in tomato farming, membership in FBO, GSZ location, price of tomato, cost of storage, and cost of postharvest losses significantly affect ME of tomato farmers in Ghana.

Table 7.11: Determinant of Tomato Farmers' Marketing Efficiency

Variables	Coeff.	S. E
Sex	-3.420	4.622
Education	6.539***	3.492
Experience in tomato farming	-0.464***	0.178
Membership in FBO	-1.158**	0.516
GSZ	-1.268**	0.660
FSTZ	-3.787	6.668
Price of tomato	0.120***	0.009
Cost of storage	-0.031*	0.019
Cost of transportation	-0.001	0.013
Cost of postharvest losses	-0.019***	0.002
Constant	5.483	2.286
F-stat	48.310	
Prob>F	0.000	
R-squared	0.874	
Number of observations	508	

Source: Author's Estimations from Field Survey, 2020

Education is statistically significant at 1% level, indicating that education is an important factor explaining the ME of tomato farmers. The coefficient of education is positive (6.539), suggesting that the ME of tomato farmers will increase by 6.539 units if the individual attains one more year in formal education, *ceteris paribus*. This result meets the *a priori* expectation as better education enables one to acquire the vital skills on how best to strategize and to adapt to improved marketing conditions (Laper et al., 2003; Obasi, 2008). The finding is consistent with the findings of Wongnaa et al. (2014) using tomato market intermediaries in the Ashanti Region of Ghana and Offor et al. (2016) using yam marketers in Umuahia North Local Government Area of Abia State, Nigeria;

but disagrees with Farayola et al. (2013) using smallholder cocoa marketers in Oyo State, Nigeria, who found a negative and significant influence of education on ME.

The coefficient of experience in tomato farming is negative (-0.464) and significantly affected ME at 1% level, implying that a one-year increase in tomato farming will reduce ME by 0.464 percentage points if other things remain unchanged. The finding disagrees with Offor et al. (2016) who revealed that marketing experience had a positive and significant influence on ME. As opined by, Okoye (2011) marketing experience tends to reduce transaction costs due to the individual's ability to escape long and complex marketing chains, which in turn increases ME. However, the result of this study proves otherwise, as less-experienced farmers had a higher ME.

Membership in FBO has a significant, but negative effect on ME at 5% level. The coefficients of membership in FBO (-1.158) indicates that ME will reduce by 1.158 percentage points if the farmer belongs to an FBO. FBOs offer farmers the opportunity to access information and learn improved marketing practices which tend to increase the ME of farmers. The result is consistent with the finding of Farayola et al. (2013) in Oyo State, Nigeria who revealed that membership in cooperatives had a positive and significant effect on ME.

The coefficient of the price of tomato (0.120) is also found to have a positive and statistically significant relationship with the ME of tomato farmers at 1% level. This indicates that for a one Ghana cedi increase in the selling price of 72kg of fresh tomato, ME will increase by 0.120 percentage points. This result is also in tandem with the finding of Farayola et al. (2013) in Oyo State, Nigeria but disagrees with the findings of

Nwaru et al. (2011) who found a negative and statistically significant relationship between profit and purchase price per unit of vegetables in Umuahia Agricultural Zone of Abia State, Nigeria.

The location of farmers and their potential markets could be an important factor in encouraging farmers to increase their sales (Makhura, 2001). According to the results, living in GSZ has a negative and statistically significant effect on ME, further indicating that farmers located in GSZ are less efficient in the marketing of fresh tomato compared to their counterparts in CSZ. The coefficient of GSZ suggests that farm households located in GSZ improved their ME by 1.268 percentage points compared to those in CSZ at 5% significance level.

Also, the cost of storage is found to have a negative and statistically significant coefficient (-0.031) at 10% level. This result implies that an increase in the cost of storage by one Ghana Cedi will lead to a decrease in ME by 0.031 percentage points. This finding meets *a priori* expectation because tomato is a highly perishable product and for this reason increasing storage cost would imply higher marketing cost which in turn leads to a decrease in net margins.

Additionally, the cost of postharvest losses had a negative and significant effect on ME at 1% level. The coefficient of cost of postharvest losses (-0.019) suggests that for a one Ghana Cedi increase in the cost of postharvest losses, marketing efficiency will decrease by 0.019 percentage points.

CHAPTER EIGHT

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

8.0 Introduction

This final chapter of the study draws conclusions and policy recommendations from the key findings. The chapter also outlines the limitations and contributions of the study.

8.1 Summary

Tomato is one of the most highly consumed vegetables in Ghana. However, available evidence shows that domestic production falls short of the national demand. This necessitates the need for the promotion of improved technologies that can improve production and household welfare of farmers.

In summary, the thesis comprises five objectives: determinants of the adoption of ITSV, the impact of adoption on welfare, technical efficiency, the impact of adoption on technical efficiency and marketing efficiency and its determinants. Each objective is analyzed using a varied economic model. Multinomial endogenous switching regression was employed to analyse the determinants of farmers' adoption of ITSV and the effect of adoption on welfare. On the impact of adoption on production efficiency, we specified a metafrontier stochastic frontier model to estimate MTE and employed propensity score-matching technique to address self-selection bias. Market margins and Ordinary Least Squares were also used in the analysis of marketing efficiency and its determinants.

The study utilized household-level data collected using multi-stage sampling techniques to examine the production and marketing efficiencies in tomato farming and the impact of ITSV adoption on efficiency and household welfare. Based on field observation, the response variable (ITSV) is grouped as: Adoption of Pectomer (PSV), adoption of Power Roma (PRSV), and the joint adoption of pectomer (PSV) and Power Roma. This paved the way for the adoption of a non-correlation and mutually exclusive model of multinomial logit.

Key findings

On the adoption of ITSV, majority (51.18%) of the farmers adopted PSV followed by PRSV (33.27%) with non-adopters being TMSV (15.55%). The PSV adoption was also the highest in the three agro-ecological zones. Various reasons such as high yielding ability, resistance to pest and good storage ability were given for adoption of the ITSV and the non improved .This implies, farmers on a whole are willing and have adopted the ITSV over the traditional variety. The multinomial logit model results also indicated that sex of a farmer, household income, access to credit, and farmer residency in both GSZ and FSTZ positively influenced the adoption of PSV. Farmers' tertiary education, extension contact and perception about potential yield influenced the adoption of PSV negatively. Further, the adoption of PRSV was positively affected by sex of the farmer, household size, primary occupation, household income, access to credit, membership in FBO and farmers' residency in FSTZ significantly. Farmers' contact with extension officers and perception about potential yield negatively influenced the adoption of PRSV. Sex, household size, household income, access to credit, perception about market availability and farmer residency are significant and positively influenced tomato farmers' adoption of both PSV/PRSV, while tertiary education and perception about potential yield were significant and negatively associated with the adoption of both

PSV/PRSV. This also implies that, farmers adopt the various ITSV based on some socioeconomic factors and varietal characteristics. Hence measures to increase the adoption of ITSV could be channel through FBO and extension agent by sensitizing farmers on the importance of ITSV their production efficiency and wellbeing.

Secondly, the average treatment effects of TSV adoption on household welfare (including household income, household expenditure and household assets) were estimated using the multinomial endogenous switching regression. The Rho ($\lambda 0$, $\lambda 1$ and $\lambda 3$) coefficients based on the adoption of PRSV, PSV/PRSV, and TMSV were significant, implying that there is the presence of endogeneity which was corrected. The adoption of improved varieties had the greatest impact on household welfare compared to TMSV adoption.

Thirdly, the traditional stochastic frontier and the new two-stage meta-frontier were estimated to determine the factors influencing tomatoes output and technical inefficiency in the selected agro ecological zones. Results of translog SPF showed that increases in land, seeds, insecticides, and tractor services significantly increased tomato output in FSTZ and CSZ while they decreased tomato output in GSZ. Also, education, membership in FBOs, and access to extension services significantly reduced technical inefficiencies while farming experience significantly increased technical inefficiencies in GSZ. Females and farmers with access to extension services had higher technical inefficiencies in FSTZ. In addition, farmers who engaged in tomato production as their primary occupation in CSZ were found to be more technically inefficient compared with their counterparts in FSTZ and GSZ. Metafrontier technical efficiency (MFTE) and technology gap ratios (TGRs) of tomato farmers of the stochastic production metafrontier were estimated to be above 80%. However, farmers in FTSZ achieved the highest mean MFTEs and TGRs, followed by CSZ and GSZ. Similarly, farmers in FTSZ achieved the highest mean technical efficiency, compared to farmers in CSZ and GSZ. Farmers in the FSTZ have MTE over the GSZ and CSZ due to easy access to credit from both formal and informal sources and also as a result of they enjoying cheap labor due to the presence of the youth from the GSZ who travelled to the transitional zones in search of livelihood.

In addition, adoption of improved variety is found to have significant impact on farmers' production efficiency. The results showed that the group-specific TE scores increased with the adoption of improved tomato seed varieties. Thus, adopters of improved tomato seed variables were seen to be more technically efficient compared to the adopters of the local variety. For example, farmers who adopted pectomer and both pectomer and power roma, had mean TE of 93.1% and 90.9% respectively, compared to 86.2% and 88.8%, had they not adopted. In other words, farmers who adopted pectomech and both pectomer and power roma would have become 6.9% and 2.1% less efficient had they not adopted.

Finally, the marketing efficiency levels and the determinants of tomato farmers' marketing efficiency were analyzed using marketing margins and OLS. It was revealed that, retailers had the highest marketing efficiencies which was far more than the break-even point (350%), compared to farmers and wholesalers, who on average, made surpluses of 296.33% and 213.08% respectively. They also incurred the least marketing cost (GH¢30.00), compared to the cost of wholesaling (GH¢ 65.00) and production (GH¢42.00 per 72kg). This implies that, the retailers have the power in dictating the marketing for toamtoes, Therefore policy toward the improvement of tomato marketing (pricing) should be targeted through retailers. The OLS regression results revealed education and price of tomato as positive and significant determinants of marketing efficiency for tomato farmers. On the other hand, experience in tomato farming, membership in FBO, GSZ location, cost of storage and cost of postharvest losses had a significant negative effect on marketing efficiency of tomato farmers in Ghana.

8.2 Conclusions

Tomato production in Ghana is an important activity, especially for the youth and people with no formal education. The cultivation of improved varieties (Pectomer, Power Roma), Pectomer/ Power Roma or the traditional variety ("Techiman") by farmers was based on their perceptions of the varietal characteristics and some socioeconomic factors. The adoption of ITSV led to increased farmers' technical efficiency and household welfare.

In addition, tomato farmers in Ghana produced below the group frontier due to limited and inefficient utilization of the available technologies and some socioeconomic variables.

Similarly, the adoption of improved varieties increases the efficiency of tomato production in Ghana. Thus, adopters of improved tomato seed variables are seen to be more technically efficient compared to the adopters of the local variety.

Finally, Tomato production in the three selected agro-ecological zones was not very profitable as compared to marketing of tomato. Farmers had the least market power and marketing efficiency compared to wholesalers and retailers.

8.4 Policy Recommendations

This study has provided important policy options for promoting smallholder tomato production and rural welfare in Ghana, where crop productivity remains low.

First of all, adoption of improved tomato seed varieties could serve as an additional production strategy for achieving sustainable smallholder tomato production and improving household welfare in Ghana.

The study suggests that any effort aimed at increasing tomato farmers' adoption of improved tomato varieties should be directed through trained extension agents who will effectively create awareness of the varietal characteristics. Most importantly, research institutions such as CSIR and tertiary institutions should increase production and farmers' access to improved seed varieties with high-yielding capability, tolerance to pests, spoilage, and bad weather.

Both public and private sector should promote improved tomato seed varieties to improve adoption in all three agro-ecological zones studied.

Another policy implication of the study is that, to boost technical efficiency and maintain positive welfare impact of improved tomato seed variety adoption, complementaty inputs (machines and agrochemical) should be made more accessible to farmers in all the three agro-ecological zones. That is the private sector, including financial institutions, value chains, and NGOs as well as the government, through MoFA, should support FBOs, and also assist tomato farmers to access extension services to help eliminate technical inefficiencies in tomato production.

The study also suggests that to boost marketing efficiency of tomato farmers in the selected agro-ecological zones of Ghana, efficient transport and storage facilities should be improved at farm-gate level.

The MoFA Buffer Stock Company should include tomatoes in its trading services to farmers. Again the buffer stock program should be strengthened to buy farm produce and stabilize prices so as to minimize exploitative power of market queens and retailers in the tomato value chain.

It is also recommended that organizations, such CSIR, ADVANCE and IWAD that are implementing farm intervention programmes should extend their operations to cover more farmers to take advantage of their support.

In conclusion, this study argues for a more robust and a broader approach to improving the welfare of the rural livelihoods in the study area through agricultural technology transfer, financial support and infrastructure for storage.

8.5 Contributions of the Research

Policy-wise, this study contributes to the development of domestic tomato production in Ghana and supports the increasing call on government to address high importation of fresh tomato by identifying the key factors needed to increase improved seed variety adoption, and production and marketing efficiencies of tomato farmers.

Also, the study is unique in that it uses three agro-ecological household data to evaluate the impact of tomato seed variety adoption choices on household welfare. The use of the MESR means that biases in household welfare due to differences in TSV adoption were eliminated. The positive contribution of improved variety adoption on household welfare can also encourage potential investors to engage in tomato production.

In addition, this study employs the multinomial endogenous switching regression in determining the factors influencing the adoption of ITSV and the impact of adoption on efficiency. This model offerred evidence of production efficiency bias and consequently corrected using the multinomial endogenous treatment framework.

Finally, the study contributes to literature by establishing the marketing efficiency and the determinants of marketing efficiency in the tomato value chain in Ghana.

8.6 Limitations and Suggestions for Future Research

This study used current and rigorous econometric procedures to arrive at important conclusions. However, there are some limitations which are worth mentioning.

The study used cross-sectional data which do not account for seasonal variation. The study therefore suggests that future studies may be carried out to account for seasonal variations and the long-run effect of ITSV adoption on household welfare in Ghana.

Also, the study employed the stochastic meta-frontier analysis, otherwise known as the group benchmarking technique. This method has been criticized on its ability to provide policy directions for improving farm specific productivity. This is attributed to the possibility of farmers or firms operating in different environmental conditions, making it impossible for specific farm policy but rather group specific. The study thereforesuggests that future studies could use the behavioral approach which seeks to look at efficiency individually based on some behavioral characteristics.

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Appendix 1

Farmers Research Questionnaire

This Survey Questionnaire (SQ) is designed to solicit information on Tomatoes Seed variety adoption, efficiency and welfare analysis of farmers in selected Ecological Zones of Ghana, solely for academic purpose. Your assistance by objectively answering the questions is vital to the validity of the research. The research team wishes to inform you that, data collected will be de-identified before analysis to ensure anonymity. You are therefore invited to participate in this research voluntarily due to your location and occupation. Thank you for your co-operation.

Questionnaire number:…………….. Name of Community: …………………

Date: ……/……../2019 Time (start): …….. … (End):

Section I: Demographic Characteristics

1. Type of Agro ecological Zone
   - ☐ Guinea Savanna Zone (GSZ)
   - ☐ Forest Savanna Transition Zone (FSZ)
   - ☐ Coastal Zone (CZ)
2. What is your ethnicity?
   - ☐ Mole-Dagbani
   - ☐ Gurma
   - ☐ Guans
   - ☐ Akan
3. Religion of Respondent:
   - ☐ Christian
   - ☐ Muslim
   - ☐ Traditional
4. Marital Status of Respondent:
   - ☐ Single
   - ☐ Married
   - ☐ Divorced
   - ☐ Widow
   - ☐ Widower

5. What is your household size…………………………………..

6. How many are children, (below 18)…………..and how many are adult (above18)…………

7. For the respondents

Age	**Sex M/F**	**Highest Education**	**Major occupation** *(Activity you spend most of your time on)*	**Earnings/ Month (GH₵)**

8. If respondents is not the household head,

What is the relationship of the respondents with the household head	*Marital status*	*Age(in years)*	*Sex M/F*	*Highest Education*	*Major occupation (Activity you spend most of your time on)*	*Earnings/ Month (GH₵)*

NB
(1) None, (2) Koranic school, (3) Non-formal (can read and write but never went to school), (4) primary class (1-6), (5) Junior High School (JHS1 – JHS3) (6) Secondary (SHS1-SHS3, Vocational or Technical School, (7) Tertiary (Training college, university, polytechnic)
(1) Own farm, (2) daily wage labour (farming or non-farm activities), (3) salaried worker (e. g. teacher, police man), (4) petty trading, (5) craftsman (e. g. bricklayer, carpenter, tailor), (6) Student, (7) Other **(***Please specify:*) (1) married, (2) single (3) divoice

If the respondents primary occupation is farming in Q 8?

9. How long have you been engaged in the farming?...............................

10. Are you aware of farmer base organizations?
    - ☐Yes
    - ☐No

If yes to Q11,

11. Are you a member of farmer base organization (FBO)?
    - ☐Yes
    - ☐No

12. If yes to Q 12, what is the name of the FBO……………………………

13. If no to Q 12, why: Please give reasons……………………………………

14. Are you aware of agricultural insurance policy?
    - ☐ Yes
    - ☐ No

    If yes to Q15,
15. Are you a member of any agricultural insurance policy?
    - ☐ Yes
    - ☐ No

16. If yes to Q 16, what is the name of the agricultural insurance policy…………………

17. If no to Q 16, why: Please give reasons……………………………………

18. How much policy did you buy in (GH₵)…………………………………

19. What is the maximum amount you are WTP for the policy (GH₵)…………………

Section II: Farmers' Decision to adopt Tomatoes Seed Variety

20. Are you aware of any tomatoes seed varieties?
    - ☐ Yes
    - ☐ No

21. If yes to Q 21, how did you become aware? (Tick more than one if applies)

Source	**Please tick**
Friends	
MoFA Office	
Input Dealers	
Relatives	
Ngo	
FBO	
Others, (Please specify)	

22. If No to Q21 please move to question 27

23. If yes to Q.21, have you adopted any of these tomatoes seed varieties in your last production? (Tick)

Tomatoes seed variety	YES	NO
Power Roma *(PR)*		
Pectomech *(P),*		
Non Adoptors (Techiman *(T))*		

24. If yes to Q.24, what are the reasons for adopting a particular tomato seed variety? (Please rank: 1 for highest; 9 for lowest)

Reasons	Rank
Increase in yield (potential yield)	
A ready market for the output	
Access to seed	
Resistance to pest and diseases	
Shorter maturity period	
Low cost of seed	
Extension service	
Good storage ability	
Others(please specify)	

25. If no to Q.24, what are the reasons for not adopting a particular tomatoes seed variety? (Please rank: 1 for highest; 9 for lowest).

Reasons	Rank
High cost of seed	
Seed not available	
Inadequate land	
Requires high skills	
Poor taste	
Requires a high amount of rainfall	
Religious restrictions	
Cultural restrictions	

Section III: Soil Fertility Indicators

What is the fertility of the land used for tomatoes cultivation in 2018

☐ Good
☐ Average
☐ Poor

26. What is the slope of the land used for tomatoes cultivation in 2018?

☐ Flat

☐ Medium slope
☐ Steep

27. What is the colour of the soil used for tomatoes cultivation in 2018?
   ☐ Black
   ☐ Brown
28. What is the Soil depth used for tomatoes cultivation in 2018?
   ☐ Shallow
   ☐ Medium
   ☐ Deep

29. What method did you use for ploughing land used for tomatoes cultivation in 2018?
   ☐ Tractor
   ☐ Animal traction
   ☐ Hand/Manual

30. What method did you used in harvesting tomatoes in 2018?
   ☐ Tomato harvester (machine)
   ☐ Hand/Manual
   ☐ Others, specify---

31. Imagine a hectare of land yields seven basins of tomatoes in a season, how many extra basins of tomatoes will you require to switch from traditional tomato variety to non-traditional tomato variety? ---------------------------------

32. How do you acquire land for tomatoes cultivation? Please, rank?

Section IV: Land Issues

Source of land for tomatoes farming in 2018	**Rank in percentage (100%)**
Personal	
Family	
Friends	
Share cropping	
Chiefs	
NGO	
Others (please specify)---------------------	
Total (100%)	

Section V: Output and Inputs in Tomatoes Production

33. Please complete the table below using last season figures

34. Quantity of tomatoes harvested in (Kgs)……………………………………

35. How long have you been cultivating tomatoes (in years)…………………………….

36. What is the distance from your house to the tomato farm in (km)? …………………..

37. Do you experience some pest on your farm?
- ☐ Yes
- ☐ No

38. Do you experience some diseases on your farm?
- ☐ Yes
- ☐ No

Adopted Tomatoes Seed Variety		
Inputs	**Quantity**	**Unit cost**
Tomatoes seed (Kgs)		
Labour (days) Hired		
Labour (days) fertilizer Kgs)-NPK		
Weedicide (liters)		
Insecticide(Liters)		
Land size (Hectares)		
Fertilizer(Kgs) Amonia		
Fertilizer (Kgs) NPK		
Others please specify		

39. What type of farming system are you engaged in?
- ☐ Single Cropping
- ☐ Mixed Cropping

40. If mixed cropping, list the crop(s) grown with tomatoes…………………......

41. Did you receive any extension services during 2018 production?
- ☐ Yes
- ☐ No

42. If yes, how many times do you received extension service in a year?................. times

43. Are you aware of credit (inputs, cash etc) for farmers?
    - ☐ Yes
    - ☐ No

44. If yes to Q.45, do you have access to credit?
    - ☐ Yes
    - ☐ No

45. If yes to Q.46, what kind of credit do you have access to?
    - ☐ Formal credit
    - ☐ Informal credit

46. If yes to Q.45 How much of either of the credit do you receive in a year? GH₵…………………

47. How much of the credit do you require in a year? GH₵………………………

48. If no (Q.45) why?
    - ☐ Demand for huge collateral
    - ☐ High interest rate
    - ☐ High repayment rate
    - ☐ Ignorance
    - ☐ Others (specify) ……………………

49. What is the source of your water for tomato farming?
    - ☐ Rain water
    - ☐ Dump

50. Do you use irrigation facility
    - ☐ Yes
    - ☐ No

51. If yes to Q51, how much in cost do you incur for the irrigation? GH₵………………

52. If No to Q51, please specify your reasons………………………………

53. Does the adoption or not adopting tomatoes seed variety, affect your wellbeing as in

54. If yes to Q55, how does it affect your wellbeing?
   - ☐ Positive
   - ☐ Negative

55. If No to Q55, Please move to Q.58

Indicators of welfare	**YES**	**NO**
Total income		
Assets (Tangible and intangible)		
Education		
Shelter		
Food		
Clothing		

Section VI: Household Expenditure

56. Please complete the table below using last season (2018) monthly expenditure figures

EXPENDITURE (ITEM)	COST (GH₵)
Food	
Water	
Shelter (home or room)	
Clothing	
Transport (motor, car bicycle)	
Fuel	
Electricity	
Gas (LPG)	
Phones	
Phone credit	
Television bills	
School fees	
Health (hospital bills)	
Funs/Fridge	
Computers (table top, lab top notebook)	
Pressing iron	
Microwave	
Sound System	
Room drawer	
Kitchen drawer	
Meat for food (fish, beef)	
Radio	
Others please specify	

57. What other non-monetary indicators do you think improves upon your welfare as a tomato farmer?

Please specify---

58. What other non-monetary indicators do you think improves upon your welfare as a tomato marketer?
Pleasespecify...

Section VII: Marketing Efficciency

59. Where do you mainly sell your tomatoes?
    - ☐ At the farm gate
    - ☐ At home
    - ☐ By the roadside
    - ☐ At the community market center
    - ☐ Other places (specify) ……………

60. Whom do you mainly sell your tomatoes to?
    - ☐ Consumers
    - ☐ Retailers
    - ☐ Wholesalers
    - ☐ Any available buyer

61. What time of the year do you normally harvest your tomatoes?
    - ☐ July-Sept
    - ☐ Oct-Dec
    - ☐ Jan-March
    - ☐ April-June
    - ☐ All year round

62. What time of the year do you normally sell out tomatoes?
    - ☐ July-Sept
    - ☐ Oct-Dec
    - ☐ Jan-March
    - ☐ April-June
    - ☐ All year round

63. How much did you sell your tomatoes (1 basin) the last farming season (2018)?

Please indicate the price of tomatoes per a basin with respect to variety and size

no	Tomatoes variety	Larger basin price (GH₵)	Medium basin price (GH₵)	Smaller basin price (GH₵)	Average price of a basin (GH₵)
1.					
2.					
3.					

64. Who determines the price of your tomatoes?
- ☐ Myself
- ☐ Wholesalers/Market queens
- ☐ Tomatoes marketers association
- ☐ Bargaining

65. What months do you normally receive high prices for your tomatoes?
- ☐ July-Sept
- ☐ Oct-Dec
- ☐ Jan-March
- ☐ April-June
- ☐ All year round

66. What months do you normally receive low prices for your tomatoes?
- ☐ July-Sept
- ☐ Oct-Dec
- ☐ Jan-March
- ☐ April-June
- ☐ All year round

67. How long are you able to store the tomatoes, indicate per variety in the table below:

NO	Tomatoes Variety	Storage length (days , months)
1.		
2.		
3.		

68. Indicate the cost incurred and the losses made in marketing your tomatoes after harvest.

Marketing activity	Cost per unit volume (GH₵)	Post-harvest loss (GH₵)
Storage		
Transportation (motor king, truck, tractor)		
Loading		
unLoading		
Tax/duty		
Others (specify)		

THANK YOU FOR YOUR COOPERATION

Tomato Actors Research Questionnaire

This Survey Questionnaire (SQ) is designed to solicit information on ***tomato actors marketing cost, marketing efficiency and its determinants in selected market across the selected Ecological Zones of Ghana***, solely for academic purpose. Your assistance by objectively answering the questions is vital to the validity of the research. The research team wishes to inform you that, data collected will be de-identified before analysis to ensure anonymity. You are therefore invited to participate in this research voluntarily due to your location and occupation. Thank you for your co-operation.

Section I: Trader's Characteristics

1. Sex Male [ ] Female [ ]

2. Age………… 3. Marital status Single [ ] Married [ ] Divorced [ ] widowed [ ]

4. What is your highest level of education a. primary [ ] b. secondary [ ] c. tertiary [ ]

d. others (specify) ………………………….

5. How many of you in your house eat from the same pot? ……………………

6. How long have you being in tomatoes trade …………… years

7. What type of tomatoes wholesaler are you? a. Itinerant [ ] b. Resident [ ]

8. Do you have a market store? a. Yes [ ] b. No [ ]

Section II: Marketing Channels

9. Do you engage in any other form of economic activity? a. Yes [ ] b. No [ ]

10. Where do you normally buy your tomatoes? a. at the farm gate [ ] b. in farmers home [ ] c. by the roadside [ ] d. at the market center [ ] e. other places (specify) ……………….,…………….And why do you buy at this point? ………………

11. How much tomatoes (72kg) do you buy annually for sale? ……………….

12. How much do you buy the tomatoes (72kg) GH¢ ………………..

13. Where do you mainly sell your tomatoes? a. at home [ ] b. by the roadside [ ] c. at the community market center [ ] d. other places (specify) ……………….,………. And why do you sell at this point? ……………………………………………..…

14. Whom do you sell your tomatoes to? a. Consumers [ ] b. Retailers [ ] c. Other wholesalers [ ] d. tomatoes processing companies [ ] e. Any available buyer [ ] and why? ……………………………

15. Where do your buyers take the tomatoes? …………………………………

16. Do you have preference for some tomato varieties in your tomatoes business?

a. Yes [ ] b. No [ ]

If yes indicate the varieties you buy (rank according to importance and indicate reason)

Variety	Rank	Quantity	Reason

Section III: Institutional Issues

17. Do you belong to any tomatoes trader organization? a. Yes [ ] b. No [ ]

18. What benefits do you gain from being a member of this group? …

19. Do you have access to any form of credit/support/aids for your tomatoes business? Yes [ ] No [ ] If you have access to any form of credit please indicate your source a. Banks [ ] b. District Assembly [ ] c. Cooperatives [ ] d. Relatives and friends [ ] e. Personal savings [ ] f. Other (specify) ……………………….

20. If no, why? a. Demand for huge collateral [ ] b. High interest rate [ ] c. Hidden charges [ ] d. High repayment rate [ ] e. Ignorance [ ] f. Others (specify) ……………

21. Do you have any insurance policy for your business? a. Yes [ ] b. No [ ]

Section IV: Marketing Cost and Pricing

22. What time of the year do you normally buy the tomatoes a. July-Sept [ ] b. Oct-Dec [ ] c. Jan-March [ ] d. April-June [ ]

23. When do you normally sell out the tomatoes? a. July-Sept [ ] b. Oct-Dec [ ] c. Jan-March [ ] d. April-June [ ]

24. How much do you sell your tomatoes of 72kgs? GH¢ ………………………………

25. Who determines the price of the tomatoes when you are selling it? a. Myself [ ] b. Yam Marketers association [ ] c. tomatoes Producers Association [ ] d. Bargaining [ ]

26. When do you receive high prices for the tomatoes? a. July-Sept [ ] b. Oct-Dec [ ] c. Jan-March [ ] d. April-June [ ] 27. When do you receive low prices for your tomatoes? a. July-Sept [ ] b. Oct-Dec [ ] c. Jan-March [ ] d. April-June [ ]

28. Indicate the cost incurred and the losses made in the tomatoes marketing process

MARKETING ACTIVITY	**COST PER UNIT (72kg) GH¢**	**LOSS GH¢**
Storage		
Transportation		
Truck		
Motor king		
Head pottor		
tTractor		
Others (Specify)		
Loading		
Unloading		
Tax/ duty		
Others(specify)		

THANK YOU FOR YOUR COOPERATION!

Appendix 2

TEST RESULTS

a. Functional form

Null hypothesis	(n)	Df	Chi-Square Test		
Cobb-Douglas functional form is appropriate			$\chi^2 - Cal$	$\chi^2 - Crit$	$\rho - Values$
GSZ	250	21/49	114.54	34.39	0.000
FSTZ	158	21/49	43.62	34.39	0.0012
CSZ	100	21/49	40.11	34.39	0.0016
Metafrontier	508	21/49	230.37	34.39	0.0000
No inherent inefficiency					
GSZ	250	38/39	128.37	29.41	0.0000
FSTZ	158	38/39	58.76	29.41	0.0000
CSZ	100	38/39	53.95	29.41	0.0005
Metafrontier	508	38/49	117.54	29.41	0.0000
Homogeneous technologies					
There are no differences in technologies used in GSZ, FSTZ and CS	508	38/49	121.12	65.81	0.0002

b. *Hausman Test for Endogeneity(IIA)*

```
. hausman cest .

                    b = consistent under Ho and Ha; obtained from mlogit
         B = inconsistent under Ha, efficient under Ho; obtained from mlogit

    Test:  Ho:  difference in coefficients not systematic

                 chi2(16) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =    -7.34    chi2<0 ==> model fitted on these
                                        data fails to meet the asymptotic
                                        assumptions of the Hausman test;
```

c. RAMSEY: Regression Equation Specification Error Test

```
. estat ovtest

Ramsey RESET test using powers of the fitted values of marketingeff
       Ho:  model has no omitted variables
                 F(3, 228) =     20.55
                  Prob > F =      0.0000
```

```
. linktest

      Source |       SS           df       MS      Number of obs   =       241
-------------+----------------------------------   F(2, 238)       =     75.09
       Model |   144469587         2  72234793.3   Prob > F        =    0.0000
    Residual |   228957327       238  962005.574   R-squared       =    0.3869
-------------+----------------------------------   Adj R-squared   =    0.3817
       Total |   373426913       240  1555945.47   Root MSE        =    980.82

------------------------------------------------------------------------------
marketingeff |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        _hat |  -.3133449   .2600814    -1.20   0.229    -.8257004    .1990107
      _hatsq |   .0004321   .0000802     5.39   0.000     .0002741      .00059
       _cons |   788.9423   209.7437     3.76   0.000      375.751    1202.134
```

d. production efficiency results

Iteration 14: log likelihood = -416.41351

Stoc. frontier normal/half-normal model

Log likelihood = -416.41351

Number of obs = 508
Wald chi2(35) = 196.14
Prob > chi2 = 0.0000

lnOutput	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lnOutput						
lnLand	.3172212	.0851945	3.72	0.000	.150243	.4841993
lnLabor	-.0730045	.0259042	-2.82	0.005	-.1237757	-.0222332
lnFert	.0924312	.0542743	1.70	0.089	-.0139444	.1988068
lnseeds	.1785568	.0616542	2.90	0.004	.0577167	.2993969
lnherb	.1089897	.0388038	2.81	0.005	.0329356	.1850438
lninsect	-.0362705	.0501021	-0.72	0.469	-.1344688	.0619278
lntractor	.0386934	.033272	1.16	0.245	-.0265186	.1039053
lnLand_sq	.0843334	.0903065	0.93	0.350	-.0926641	.2613309
lnLabor_sq	.0373032	.0159025	2.35	0.019	.0061349	.0684715
lnFert_sq	-.0106882	.0289403	-0.37	0.712	-.0674102	.0460338
lnseeds_sq	-.0877544	.1088743	-0.81	0.420	-.3011442	.1256354
lnherb_sq	-.0222603	.0726581	-0.31	0.759	-.1646674	.1201469
lninsect_sq	.055538	.1001819	0.55	0.579	-.1408149	.2518909
lntractor_sq	.0083177	.006738	1.23	0.217	-.0048886	.021524
lnLand_Labor	.0107911	.0590264	0.18	0.855	-.1048985	.1264807
lnLand_Fert	.268377	.0531226	5.05	0.000	.1642586	.3724954
lnLand_seeds	-.1028741	.1066781	-0.96	0.335	-.3119593	.1062112
lnLand_herb	-.0962017	.074066	-1.30	0.194	-.2413685	.048965
lnLand_insect	.0184922	.0813186	0.23	0.820	-.1408894	.1778737
lnLand_tractor	.0021332	.0096285	0.22	0.825	-.0167384	.0210048
lnLabor_Fert	-.099134	.0401362	-2.47	0.014	-.1777996	-.0204684
lnLabor_seeds	-.3070326	.1057631	-2.90	0.004	-.5143246	-.0997407
lnLabor_herb	.0109091	.057817	0.19	0.850	-.10241	.1242283
lnLabor_insect	.0161477	.0700244	0.23	0.818	-.1210976	.153393
lnLabor_tractor	.0199218	.0102056	1.95	0.051	-.0000808	.0399243
lnFert_seeds	.0720776	.1055634	0.68	0.495	-.1348228	.2789781
lnFert_herb	.0680204	.0637883	1.07	0.286	-.0570024	.1930432
lnFert_insect	.0004341	.0653796	0.01	0.995	-.1277075	.1285758
lnFert_tractor	.002067	.0074313	0.28	0.781	-.0124981	.0166322
lnseeds_herb	.1135879	.1000679	1.14	0.256	-.0825415	.3097173
lnseeds_insect	.0935828	.1149956	0.81	0.416	-.1318045	.31897
lnseeds_tractor	.0200229	.0129852	1.54	0.123	-.0054277	.0454734
lnherb_insect	-.0686092	.0710752	-0.97	0.334	-.2079141	.0706957
lnherb_tractor	-.0229595	.0082755	-2.77	0.006	-.0391792	-.0067399
linsect_tractor	-.0104981	.0095422	-1.10	0.271	-.0292004	.0082043
_cons	-.3819633	.1770489	-2.16	0.031	-.7289728	-.0349538
lnsig2v						
_cons	-1.208825	.0636408	-18.99	0.000	-1.333559	-1.084092
lnsig2u						
Sex	-1.842274	4.866119	-0.38	0.705	-11.37969	7.695144
Age	-.2063071	.1235351	-1.67	0.095	-.4484315	.0358172
Basic_education	4.83866	6.801647	0.71	0.477	-8.492324	18.16964
Secondary_education	3.822086	6.587015	0.58	0.562	-9.088226	16.7324
Tertiary_education	-20.12017	1208.181	-0.02	0.987	-2388.112	2347.872
Prim_Occu_tomatoesfarming	-1.754362	1.585674	-1.11	0.269	-4.862227	1.353502
Farm_size	.0726508	.2617305	0.28	0.781	-.4403316	.5856332
Farming_type	.5989187	1.251576	0.48	0.632	-1.854126	3.051963
FBO_membership	-2.894882	1.746512	-1.66	0.097	-6.317982	.528219
Access_to_credit	2.992375	1.64072	1.82	0.068	-.2233775	6.208127
Extension_access	-1.932119	1.81499	-1.06	0.287	-5.489433	1.625196
_cons	2.559729	7.79101	0.33	0.742	-12.71037	17.82983
sigma_v	.5463952	.0173865			.5133592	.5815572

Iteration 11: log likelihood = -139.71599

Stoc. frontier normal/half-normal model

Number of obs = 250
Wald chi2(35) = 193.46
Prob > chi2 = 0.0000

Log likelihood = -139.71599

lnOutput	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lnOutput						
lnLand	.4979789	.1623468	3.07	0.002	.179785	.8161727
lnLabor	-.0639562	.0218795	-2.92	0.003	-.1068393	-.0210731
lnFert	.1284211	.1197387	1.07	0.283	-.1062624	.3631046
lnseeds	1.384046	.506042	2.74	0.006	.3922219	2.37587
lnherb	.0711947	.0388726	1.83	0.067	-.0049941	.1473835
lninsect	-.0257458	.0402618	-0.64	0.523	-.1046575	.053166
lntractor	.0949401	.0321878	2.95	0.003	.0318533	.158027
lnLand_sq	.1726092	.1930877	0.89	0.371	-.2058358	.5510542
lnLabor_sq	.0145267	.0225669	0.64	0.520	-.0297037	.058757
lnFert_sq	-.0533333	.0499098	-1.07	0.285	-.1511547	.0444882
lnseeds_sq	.0732067	.1715053	0.43	0.669	-.2629375	.4093509
lnherb_sq	.007331	.0725969	0.10	0.920	-.1349563	.1496183
lninsect_sq	.1212793	.0921961	1.32	0.188	-.0594218	.3019804
lntractor_sq	.0255878	.0068286	3.75	0.000	.012204	.0389716
lnLand_Labor	.2530118	.0956884	2.64	0.008	.065466	.4405576
lnLand_Fert	.1479542	.0794268	1.86	0.062	-.0077195	.3036279
lnLand_seeds	-.3892682	.1545675	-2.52	0.012	-.6922149	-.0863216
lnLand_herb	-.0112036	.0889445	-0.13	0.900	-.1855317	.1631244
lnLand_insect	-.1335877	.0772888	-1.73	0.084	-.2850709	.0178956
lnLand_tractor	-.0143373	.0140735	-1.02	0.308	-.0419208	.0132462
lnLabor_Fert	-.1251917	.0726985	-1.72	0.085	-.2676782	.0172947
lnLabor_seeds	-.2856162	.1323415	-2.16	0.031	-.5450008	-.0262316
lnLabor_herb	-.0115157	.0732429	-0.16	0.875	-.1550691	.1320378
lnLabor_insect	.147793	.0874117	1.69	0.091	-.0235309	.3191168
lnLabor_tractor	-.0018793	.01713	-0.11	0.913	-.0354534	.0316948
lnFert_seeds	.2735422	.1552597	1.76	0.078	-.0307613	.5778457
lnFert_herb	-.0279891	.0752177	-0.37	0.710	-.1754131	.1194348
lnFert_insect	-.0784065	.0786024	-1.00	0.319	-.2324643	.0756513
lnFert_tractor	.0196917	.0132389	1.49	0.137	-.0062561	.0456396
lnseeds_herb	-.037621	.1228409	-0.31	0.759	-.2783847	.2031427
lnseeds_insect	.1155458	.1411304	0.82	0.413	-.1610648	.3921563
lnseeds_tractor	-.0124905	.02001	-0.62	0.532	-.0517093	.0267283
lnherb_insect	-.0771601	.0772734	-1.00	0.318	-.2286131	.074293
lnherb_tractor	.0133713	.0107653	1.24	0.214	-.0077283	.0344709
linsect_tractor	-.0065278	.0117144	-0.56	0.577	-.0294876	.016432
_cons	-.0327157	.2499334	-0.13	0.896	-.5225762	.4571447
lnsig2v						
_cons	-2.095323	.1843826	-11.36	0.000	-2.456706	-1.73394
lnsig2u						
Sex	-1.111177	.6940314	-1.60	0.109	-2.471454	.2490993
Age	.0274704	.0203143	1.35	0.176	-.0123449	.0672857
Basic_education	-.9169671	.5256032	-1.74	0.081	-1.94713	.1131962
Secondary_education	-.5398769	.8289309	-0.65	0.515	-2.164552	1.084798
Tertiary_education	-7.087385	10.07296	-0.70	0.482	-26.83003	12.65526
Prim_Occu_tomatoesfarming	.5019043	.4541208	1.11	0.269	-.3881561	1.391965
Farm_size	.3736727	.1589451	2.35	0.019	.062146	.6851993
Farming_type	-.0735664	.4263952	-0.17	0.863	-.9092857	.7621528
FBO_membership	-1.744003	.6522287	-2.67	0.007	-3.022348	-.4656588
Access_to_credit	.410206	.5426831	0.76	0.450	-.6534334	1.473845
Extension_access	-1.191638	.5126938	-2.32	0.020	-2.1965	-.1867769
_cons	-.3928922	1.422423	-0.28	0.782	-3.180791	2.395006
sigma_v	.350757	.0323367			.2927744	.4202229

Iteration 15: log likelihood = -113.18551

Stoc. frontier normal/half-normal model

Number of obs = 158
Wald chi2(35) = 120.77
Prob > chi2 = 0.0000

Log likelihood = -113.18551

lnOutput	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lnOutput						
lnLand	.0267677	.2986494	0.09	0.929	-.5585744	.6121098
lnLabor	-.0663631	.0781559	-0.85	0.396	-.2195458	.0868195
lnFert	.1096995	.081385	1.35	0.178	-.0498122	.2692113
lnseeds	.180772	.0596959	3.03	0.002	.0637703	.2977738
lnherb	.0763731	.6661997	0.11	0.909	-1.229354	1.382101
lninsect	.3176099	.8344364	0.38	0.703	-1.317855	1.953075
lntractor	-.0621463	.1228158	-0.51	0.613	-.3028608	.1785683
lnLand_sq	.3111471	.1864296	1.67	0.095	-.0542481	.6765423
lnLabor_sq	.166543	.0710978	2.34	0.019	.0271939	.3058921
lnFert_sq	-.1408231	.2590234	-0.54	0.587	-.6484996	.3668535
lnseeds_sq	.0409313	.2841196	0.14	0.885	-.515933	.5977956
lnherb_sq	.2694702	1.027392	0.26	0.793	-1.744182	2.283122
lninsect_sq	-.2468044	1.294669	-0.19	0.849	-2.784309	2.2907
lntractor_sq	-.0284086	.0235647	-1.21	0.228	-.0745944	.0177773
lnLand_Labor	.0351784	.1875261	0.19	0.851	-.332366	.4027228
lnLand_Fert	.2348154	.1680351	1.40	0.162	-.0945274	.5641581
lnLand_seeds	.1749897	.3341854	0.52	0.601	-.4800015	.829981
lnLand_herb	-.7125016	.5503632	-1.29	0.195	-1.791194	.3661905
lnLand_insect	.7389132	.6051329	1.22	0.222	-.4471255	1.924952
lnLand_tractor	-.0034995	.0241224	-0.15	0.885	-.0507785	.0437795
lnLabor_Fert	.0598551	.1638096	0.37	0.715	-.2612059	.3809161
lnLabor_seeds	.1220358	.4863217	0.25	0.802	-.8311372	1.075209
lnLabor_herb	-.1304607	.4923149	-0.26	0.791	-1.09538	.8344588
lnLabor_insect	-.250579	.5127565	-0.49	0.625	-1.255563	.7544053
lnLabor_tractor	.0949535	.0408832	2.32	0.020	.0148239	.1750831
lnFert_seeds	.5541554	.2930042	1.89	0.059	-.0201222	1.128433
lnFert_herb	.4323763	.47679	0.91	0.364	-.5021149	1.366867
lnFert_insect	-.3980413	.447625	-0.89	0.374	-1.27537	.4792875
lnFert_tractor	-.0483614	.0264716	-1.83	0.068	-.1002449	.003522
lnseeds_herb	.1968591	.6334572	0.31	0.756	-1.044694	1.438412
lnseeds_insect	-.9608791	.9711876	-0.99	0.322	-2.864372	.9426136
lnseeds_tractor	.0582911	.037462	1.56	0.120	-.015133	.1317152
lnherb_insect	.067394	1.18525	0.06	0.955	-2.255653	2.390442
lnherb_tractor	.0181552	.1012524	0.18	0.858	-.1802959	.2166062
linsect_tractor	-.0145477	.1173951	-0.12	0.901	-.2446379	.2155424
_cons	-1.592245	.9033875	-1.76	0.078	-3.362852	.1783622
lnsig2v						
_cons	-1.422248	.1130866	-12.58	0.000	-1.643894	-1.200603
lnsig2u						
Sex	-9.79955	30.23247	-0.32	0.746	-69.0541	49.455
Age	-.8881344	1.011315	-0.88	0.380	-2.870276	1.094007
Basic_education	-7.53027	30.29618	-0.25	0.804	-66.90968	51.84915
Secondary_education	10.34417	43.3675	0.24	0.811	-74.65458	95.34291
Tertiary_education	-40.27587	63.497	-0.63	0.526	-164.7277	84.17596
Prim_Occu_tomatoesfarming	1.748929	36.77941	0.05	0.962	-70.33738	73.83524
Farm_size	-16.75591	17.45008	-0.96	0.337	-50.95744	17.44563
Farming_type	-25.54853	34.12624	-0.75	0.454	-92.43473	41.33768
FBO_membership	44.23129	2562.152	0.02	0.986	-4977.495	5065.957
Access_to_credit	40.36424	59.48828	0.68	0.497	-76.23064	156.9591
Extension_access	10.44146	9.697779	1.08	0.282	-8.565838	29.44876
_cons	15.98972	2564.187	0.01	0.995	-5009.724	5041.704
sigma_v	.4910918	.027768			.4395749	.5486463

```
Iteration 16:   log likelihood = -74.400937

Stoc. frontier normal/half-normal model         Number of obs     =        100
                                                Wald chi2(35)     =      78.92
Log likelihood = -74.400937                     Prob > chi2       =     0.0000
```

lnOutput	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lnOutput						
lnLand	-.3311362	.6930822	-0.48	0.633	-1.689552	1.02728
lnLabor	-.6299481	.7130935	-0.88	0.377	-2.027586	.7676894
lnFert	-.5286524	.5057298	-1.05	0.296	-1.519865	.4625598
lnseeds	-30.47635	16.48744	-1.85	0.065	-62.79115	1.838441
lnherb	-.9948686	.7428736	-1.34	0.181	-2.450874	.4611369
lninsect	-.8537652	.5700711	-1.50	0.134	-1.971084	.2635537
lntractor	.2056052	.1443616	1.42	0.154	-.0773383	.4885488
lnLand_sq	.0906475	.2205835	0.41	0.681	-.3416883	.5229833
lnLabor_sq	.1726611	.1221937	1.41	0.158	-.0668342	.4121564
lnFert_sq	-.0844259	.1053814	-0.80	0.423	-.2909697	.1221179
lnseeds_sq	-1.443221	1.000671	-1.44	0.149	-3.4045	.5180573
lnherb_sq	-1.635172	.8491361	-1.93	0.054	-3.299448	.0291045
lninsect_sq	-.7335593	.7742804	-0.95	0.343	-2.251121	.7840023
lntractor_sq	.0281227	.0245849	1.14	0.253	-.0200629	.0763083
lnLand_Labor	-.0702192	.1728084	-0.41	0.684	-.4089174	.268479
lnLand_Fert	.2464663	.1455215	1.69	0.090	-.0387506	.5316831
lnLand_seeds	-.5451484	.5721346	-0.95	0.341	-1.666512	.5762148
lnLand_herb	.1466399	.4816021	0.30	0.761	-.7972829	1.090563
lnLand_insect	-.6699533	.4558416	-1.47	0.142	-1.563386	.22348
lnLand_tractor	-.0314986	.033377	-0.94	0.345	-.0969163	.033919
lnLabor_Fert	-.6516447	.153826	-4.24	0.000	-.953138	-.3501513
lnLabor_seeds	-.9347005	.44287	-2.11	0.035	-1.80271	-.0666912
lnLabor_herb	-.0745003	.2362947	-0.32	0.753	-.5376295	.3886288
lnLabor_insect	.7012825	.3003582	2.33	0.020	.1125913	1.289974
lnLabor_tractor	.0797558	.0298364	2.67	0.008	.0212775	.1382341
lnFert_seeds	-.3029531	.3954821	-0.77	0.444	-1.078084	.4721775
lnFert_herb	.2584399	.2441774	1.06	0.290	-.220139	.7370188
lnFert_insect	-.9198345	.3369553	-2.73	0.006	-1.580255	-.2594142
lnFert_tractor	.0006112	.0239423	0.03	0.980	-.0463147	.0475372
lnseeds_herb	-.462949	.6513969	-0.71	0.477	-1.739663	.8137654
lnseeds_insect	-1.959883	1.154435	-1.70	0.090	-4.222534	.302768
lnseeds_tractor	-.0305569	.0602085	-0.51	0.612	-.1485634	.0874496
lnherb_insect	.3766066	.3617377	1.04	0.298	-.3323864	1.0856
lnherb_tractor	.0039697	.0344834	0.12	0.908	-.0636166	.0715559
linsect_tractor	.0743546	.0537802	1.38	0.167	-.0310527	.1797619
_cons	-2.764476	1.636455	-1.69	0.091	-5.971869	.4429179
lnsig2v						
_cons	-1.47443	.1619265	-9.11	0.000	-1.7918	-1.157059
lnsig2u						
Sex	5.836786	2.745253	2.13	0.033	.4561895	11.21738
Age	-.1074144	.0740503	-1.45	0.147	-.2525504	.0377216
Basic_education	1.535269	2.141925	0.72	0.474	-2.662826	5.733365
Secondary_education	-1.34137	2.882084	-0.47	0.642	-6.990151	4.307411
Tertiary_education	-28.24785	1421.366	-0.02	0.984	-2814.074	2757.578
Prim_Occu_tomatoesfarming	3.355642	2.021804	1.66	0.097	-.6070211	7.318305
Farm_size	-.2274661	.6491319	-0.35	0.726	-1.499741	1.044809
Farming_type	1.367088	1.386693	0.99	0.324	-1.35078	4.084956
FBO_membership	-3.035307	5.15418	-0.59	0.556	-13.13731	7.066701
Access_to_credit	-.4888217	4.702442	-0.10	0.917	-9.705439	8.727796
Extension_access	2.882877	1.897721	1.52	0.129	-.836589	6.602343
_cons	-6.6865	5.768182	-1.16	0.246	-17.99193	4.618929
sigma_v	.4784446	.0387364			.4082401	.5607222

Iteration 11: log likelihood = -79.089382

Stoc. frontier normal/half-normal model — Number of obs = 508; Wald chi2(35) = 795.32; Prob > chi2 = 0.0000

Log likelihood = -79.089382

Y_hat_Pooled	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Y_hat_Pooled						
lnLand	.4407346	.0466537	9.45	0.000	.3492949	.5321742
lnLabor	-.059371	.0110947	-5.35	0.000	-.0811161	-.0376258
lnFert	.1088625	.0247573	4.40	0.000	.0603391	.157386
lnseeds	.273128	.0731021	3.74	0.000	.1298504	.4164055
lnherb	.067827	.0185255	3.66	0.000	.0315177	.1041364
lninsect	-.0439112	.0206194	-2.13	0.033	-.0843244	-.003498
lntractor	.0867644	.0153981	5.63	0.000	.0565847	.116944
lnLand_sq	.2955802	.0495384	5.97	0.000	.1984868	.3926736
lnLabor_sq	.0259811	.0077804	3.34	0.001	.0107317	.0412304
lnFert_sq	-.0243794	.0138597	-1.76	0.079	-.0515438	.002785
lnseeds_sq	.0088511	.0619846	0.14	0.886	-.1126366	.1303387
lnherb_sq	.0452617	.0386691	1.17	0.242	-.0305283	.1210517
lninsect_sq	.0884141	.0437151	2.02	0.043	.0027342	.1740941
lntractor_sq	.0203559	.0031528	6.46	0.000	.0141766	.0265353
lnLand_Labor	-.0536058	.029698	-1.81	0.071	-.1118128	.0046013
lnLand_Fert	.1823657	.0275849	6.61	0.000	.1283004	.236431
lnLand_seeds	-.0246428	.0610775	-0.40	0.687	-.1443525	.095067
lnLand_herb	-.0308289	.036893	-0.84	0.403	-.1031379	.0414802
lnLand_insect	-.0420902	.0371806	-1.13	0.258	-.1149628	.0307824
lnLand_tractor	-.0067454	.0051659	-1.31	0.192	-.0168703	.0033795
lnLabor_Fert	-.1007348	.0204476	-4.93	0.000	-.1408113	-.0606583
lnLabor_seeds	-.2482012	.0506463	-4.90	0.000	-.3474661	-.1489363
lnLabor_herb	-.0115289	.0296264	-0.39	0.697	-.0695955	.0465377
lnLabor_insect	.1223458	.0341661	3.58	0.000	.0553815	.1893101
lnLabor_tractor	.0190784	.0053645	3.56	0.000	.0085642	.0295925
lnFert_seeds	.1076414	.049778	2.16	0.031	.0100784	.2052045
lnFert_herb	.0509414	.0295178	1.73	0.084	-.0069124	.1087952
lnFert_insect	-.0712596	.029831	-2.39	0.017	-.1297273	-.0127919
lnFert_tractor	.0068668	.0036102	1.90	0.057	-.000209	.0139427
lnseeds_herb	.0140374	.0538788	0.26	0.794	-.0915632	.1196379
lnseeds_insect	.1175404	.0604162	1.95	0.052	-.0008732	.235954
lnseeds_tractor	.0157301	.0067624	2.33	0.020	.0024761	.0289842
lnherb_insect	-.057458	.0356506	-1.61	0.107	-.1273319	.012416
lnherb_tractor	-.0233449	.004169	-5.60	0.000	-.0315159	-.0151738
linsect_tractor	.0057789	.0045496	1.27	0.204	-.0031381	.014696
_cons	.0340326	.0872018	0.39	0.696	-.1368798	.2049451
lnsig2v						
_cons	-3.380212	.2192452	-15.42	0.000	-3.809925	-2.950499
lnsig2u						
Sex	.0104909	.2377208	0.04	0.965	-.4554333	.4764151
Age	-.0081067	.0092299	-0.88	0.380	-.0261971	.0099836
Basic_education	.3596812	.2172222	1.66	0.098	-.0660666	.7854289
Secondary_education	.272016	.4068896	0.67	0.504	-.5254729	1.069505
Tertiary_education	.0181925	.595335	0.03	0.976	-1.148643	1.185028
Prim_Occu_tomatoesfarming	-.0174221	.2349671	-0.07	0.941	-.4779492	.443105
Farm_size	.2290611	.0657612	3.48	0.000	.1001714	.3579508
Farming_type	.7662703	.1993636	3.84	0.000	.3755249	1.157016
FBO_membership	-.6398511	.4170034	-1.53	0.125	-1.457163	.1774605
Access_to_credit	-.1059989	.4030504	-0.26	0.793	-.8959632	.6839654
Extension_access	-.7403735	.2752845	-2.69	0.007	-1.279921	-.2008258
_cons	-2.011095	.7717659	-2.61	0.009	-3.523729	-.498462
sigma_v	.1845	.0202254			.1488282	.2287216

```
. sum TE_Pooled TE_Guinea TE_Forest TE_Costal TE_MetaFrontier
```

Variable	Obs	Mean	Std. Dev.	Min	Max
TE_Pooled	508	.9548418	.0756632	.4825178	1
TE_Guinea	250	.7744388	.1730844	.2349559	.9960697
TE_Forest	158	.9817129	.0939519	.046908	1
TE_Costal	100	.865116	.1729303	.2298417	.9999994
TE_MetaFro~r	508	.7711841	.1445921	.1559384	.9647247

e. Group-specific and Stochastic Metafrontier estimates

```
Iteration 10:   log likelihood = -112.03273

Stoc. frontier normal/half-normal model          Number of obs     =        164
                                                 Wald chi2(35)     =     125.84
Log likelihood = -112.03273                      Prob > chi2       =     0.0000
```

lnOutput	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lnOutput						
lnLand	.2318641	.1805494	1.28	0.199	-.1220062	.5857344
lnLabor	-.1282576	.065849	-1.95	0.051	-.2573193	.0008042
lnFert	.0128106	.0932622	0.14	0.891	-.1699799	.1956011
lnseeds	.1714045	.0631557	2.71	0.007	.0476216	.2951873
lnherb	.3268669	.0979554	3.34	0.001	.134878	.5188559
lninsect	-.0849801	.131491	-0.65	0.518	-.3426977	.1727374
lntractor	.0068431	.0565658	0.12	0.904	-.1040238	.11771
lnLand_sq	-.3528902	.1851707	-1.91	0.057	-.7158182	.0100378
lnLabor_sq	.0076565	.0370969	0.21	0.836	-.0650522	.0803651
lnFert_sq	-.0118621	.0601289	-0.20	0.844	-.1297127	.1059885
lnseeds_sq	-.2406109	.2126959	-1.13	0.258	-.6574871	.1762654
lnherb_sq	-.1647858	.1309748	-1.26	0.208	-.4214917	.0919201
lninsect_sq	-.0779005	.2153824	-0.36	0.718	-.5000422	.3442412
lntractor_sq	.0037063	.0112331	0.33	0.741	-.0183102	.0257227
lnLand_Labor	.1411459	.1391034	1.01	0.310	-.1314918	.4137837
lnLand_Fert	.2376134	.1453096	1.64	0.102	-.0471882	.5224151
lnLand_seeds	-.2006836	.1634621	-1.23	0.220	-.5210634	.1196961
lnLand_herb	-.0718244	.1529129	-0.47	0.639	-.3715281	.2278794
lnLand_insect	-.2375429	.1773821	-1.34	0.181	-.5852054	.1101195
lnLand_tractor	-.0059713	.019277	-0.31	0.757	-.0437536	.031811
lnLabor_Fert	-.1429952	.0874695	-1.63	0.102	-.3144323	.0284419
lnLabor_seeds	-.4564248	.2452894	-1.86	0.063	-.9371832	.0243336
lnLabor_herb	.0023555	.1357034	0.02	0.986	-.2636182	.2683292
lnLabor_insect	.0922331	.1631905	0.57	0.572	-.2276144	.4120805
lnLabor_tractor	.0049562	.0213002	0.23	0.816	-.0367915	.0467038
lnFert_seeds	.2233942	.1854674	1.20	0.228	-.1401152	.5869036
lnFert_herb	.0881979	.1324522	0.67	0.505	-.1714036	.3477993
lnFert_insect	.0400995	.1166006	0.34	0.731	-.1884335	.2686325
lnFert_tractor	-.014371	.0121988	-1.18	0.239	-.0382803	.0095383
lnseeds_herb	.3747896	.2120353	1.77	0.077	-.040792	.7903712
lnseeds_insect	.2802624	.226413	1.24	0.216	-.163499	.7240237
lnseeds_tractor	.0143533	.025488	0.56	0.573	-.0356022	.0643088
lnherb_insect	-.0195251	.1598357	-0.12	0.903	-.3327972	.293747
lnherb_tractor	-.0105953	.0192242	-0.55	0.582	-.048274	.0270834
linsect_tractor	-.0123429	.0215866	-0.57	0.567	-.054652	.0299661
_cons	-.0156251	.3933231	-0.04	0.968	-.7865241	.755274
lnsig2v						
_cons	-1.560597	.1244297	-12.54	0.000	-1.804475	-1.31672
lnsig2u						
Sex	-.2242719	3.141191	-0.07	0.943	-6.380894	5.93235
Education	4.043477	3.378556	1.20	0.231	-2.578371	10.66532
HH_Size	2.272623	4.097188	0.55	0.579	-5.757717	10.30296
Marital_Status	.3186671	4.169585	0.08	0.939	-7.85357	8.490904
Farming_experience	-.3939216	.303679	-1.30	0.195	-.9891215	.2012782
FBO_membership	-.023441	1.68918	-0.01	0.989	-3.334172	3.28729
Farming_type	-2.166974	1.723624	-1.26	0.209	-5.545215	1.211267
Access_to_credit	3.164229	2.022265	1.56	0.118	-.7993378	7.127797
_cons	-2.663934	5.60797	-0.48	0.635	-13.65535	8.327485
sigma_v	.4582691	.0285112			.405661	.5176998

Stoc. frontier normal/half-normal model

Number of obs = 206
Wald chi2(35) = 85.31
Log likelihood = -175.89945
Prob > chi2 = 0.0000

lnOutput	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lnOutput						
lnLand	.1819243	.1275	1.43	0.154	-.067971	.4318197
lnLabor	.0118131	.0608145	0.19	0.846	-.1073811	.1310072
lnFert	.2549705	.1501005	1.70	0.089	-.0392211	.5491621
lnseeds	.2020865	1.397736	0.14	0.885	-2.537425	2.941598
lnherb	.0436546	.0620828	0.70	0.482	-.0780253	.1653346
lninsect	-.085181	.0658638	-1.29	0.196	-.2142716	.0439097
lntractor	.0247493	.0618357	0.40	0.689	-.0964463	.145945
lnLand_sq	.1895789	.1271165	1.49	0.136	-.059565	.4387227
lnLabor_sq	.0085971	.0311977	0.28	0.783	-.0525494	.0697435
lnFert_sq	.2538959	.1262748	2.01	0.044	.0064018	.5013899
lnseeds_sq	-.1168345	.2069309	-0.56	0.572	-.5224116	.2887427
lnherb_sq	-.056339	.1998086	-0.28	0.778	-.4479567	.3352787
lninsect_sq	-.0827018	.2046925	-0.40	0.686	-.4838917	.318488
lntractor_sq	-.0002459	.0122863	-0.02	0.984	-.0243266	.0238347
lnLand_Labor	-.0322204	.0888231	-0.36	0.717	-.2063104	.1418696
lnLand_Fert	.080822	.0930742	0.87	0.385	-.1016002	.2632441
lnLand_seeds	.0498796	.2578431	0.19	0.847	-.4554837	.5552429
lnLand_herb	.0402103	.1369343	0.29	0.769	-.2281761	.3085967
lnLand_insect	-.0767456	.1448083	-0.53	0.596	-.3605647	.2070734
lnLand_tractor	-.0099964	.0179814	-0.56	0.578	-.0452394	.0252466
lnLabor_Fert	-.133399	.0787352	-1.69	0.090	-.2877171	.0209192
lnLabor_seeds	-.38442	.2057094	-1.87	0.062	-.787603	.0187629
lnLabor_herb	-.0216257	.1053204	-0.21	0.837	-.2280499	.1847986
lnLabor_insect	.0470847	.1140919	0.41	0.680	-.1765313	.2707007
lnLabor_tractor	.011182	.0161068	0.69	0.488	-.0203868	.0427507
lnFert_seeds	-.2024994	.2257849	-0.90	0.370	-.6450297	.2400308
lnFert_herb	.2499233	.1263509	1.98	0.048	.00228	.4975666
lnFert_insect	-.1641	.1349831	-1.22	0.224	-.428662	.100462
lnFert_tractor	.008155	.0151745	0.54	0.591	-.0215864	.0378965
lnseeds_herb	.3118917	.2125825	1.47	0.142	-.1047624	.7285458
lnseeds_insect	-.1715971	.2307736	-0.74	0.457	-.6239052	.2807109
lnseeds_tractor	.0451278	.0254569	1.77	0.076	-.0047668	.0950224
lnherb_insect	-.0596173	.1150244	-0.52	0.604	-.2850609	.1658264
lnherb_tractor	-.0305922	.0153178	-2.00	0.046	-.0606146	-.0005698
linsect_tractor	.0034432	.017861	0.19	0.847	-.0315638	.0384502
_cons	.0247924	.3715285	0.07	0.947	-.70339	.7529749
lnsig2v						
_cons	-1.143977	.101107	-11.31	0.000	-1.342143	-.9458104
lnsig2u						
Sex	-1.826948	3.571743	-0.51	0.609	-8.827435	5.173539
Education	3.908159	4.657803	0.84	0.401	-5.220968	13.03729
HH_Size	4.082797	4.965237	0.82	0.411	-5.64889	13.81448
Marital_Status	.1712954	11.93093	0.01	0.989	-23.2129	23.55549
Farming_experience	-.0435428	.0942849	-0.46	0.644	-.2283378	.1412521
FBO_membership	-3.508561	2.416932	-1.45	0.147	-8.245661	1.228539
Farming_type	-.7990586	1.926518	-0.41	0.678	-4.574965	2.976848
Access to credit	-.7153599	1.727676	-0.41	0.679	-4.101542	2.670822

```
 frontier normal/half-normal model             Number of obs    =       508
                                               Wald chi2(35)    =    537.27
.ikelihood = -146.60281                        Prob > chi2      =    0.0000
```

Pr_output	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ıtput						
lnLand	.282294	.0462241	6.11	0.000	.1916964	.3728915
lnLabor	-.0783167	.0153863	-5.09	0.000	-.1084733	-.0481601
lnFert	.0496355	.0320152	1.55	0.121	-.0131131	.1123842
lnseeds	.0334459	.0363468	0.92	0.357	-.0377925	.1046843
lnherb	.0913207	.0224512	4.07	0.000	.0473172	.1353241
lninsect	-.042636	.0301054	-1.42	0.157	-.1016415	.0163694
lntractor	.0555935	.020269	2.74	0.006	.0158671	.09532
lnLand_sq	.0616673	.0489712	1.26	0.208	-.0343145	.1576492
lnLabor_sq	.0393252	.0095991	4.10	0.000	.0205114	.058139
lnFert_sq	-.02844	.01709	-1.66	0.096	-.0619359	.0050559
lnseeds_sq	-.0665307	.0650453	-1.02	0.306	-.1940172	.0609557
lnherb_sq	-.0241524	.0426793	-0.57	0.571	-.1078023	.0594974
lninsect_sq	.0291	.0585735	0.50	0.619	-.085702	.1439019
lntractor_sq	.0140121	.0041609	3.37	0.001	.0058568	.0221675
lnLand_Labor	-.0086372	.0339164	-0.25	0.799	-.075112	.0578377
lnLand_Fert	.2276717	.0308849	7.37	0.000	.1671384	.288205
lnLand_seeds	-.1008514	.0629174	-1.60	0.109	-.2241673	.0224645
lnLand_herb	-.0569612	.0429418	-1.33	0.185	-.1411256	.0272032
lnLand_insect	.0185514	.0471103	0.39	0.694	-.073783	.1108859
.nLand_tractor	-.0023699	.0056127	-0.42	0.673	-.0133707	.0086309
lnLabor_Fert	-.1061376	.0235688	-4.50	0.000	-.1523316	-.0599436
lnLabor_seeds	-.2829018	.0622381	-4.55	0.000	-.4048862	-.1609173
lnLabor_herb	.0281148	.0340545	0.83	0.409	-.0386308	.0948604
.nLabor_insect	.030859	.0408381	0.76	0.450	-.0491822	.1109003
ıLabor_tractor	.012887	.00611	2.11	0.035	.0009116	.0248624
lnFert_seeds	.0122534	.0618778	0.20	0.843	-.1090249	.1335317
lnFert_herb	.0280442	.0375392	0.75	0.455	-.0455312	.1016196
lnFert_insect	-.0074332	.038006	-0.20	0.845	-.0819236	.0670572
.nFert_tractor	.006372	.0043794	1.45	0.146	-.0022115	.0149555
lnseeds_herb	.1065337	.058945	1.81	0.071	-.0089963	.2220637
.nseeds_insect	.0678146	.0680871	1.00	0.319	-.0656338	.2012629
ıseeds_tractor	.013777	.0076485	1.80	0.072	-.0012137	.0287678
lnherb_insect	-.0762118	.0422185	-1.81	0.071	-.1589585	.006535
.nherb_tractor	-.0248549	.0048076	-5.17	0.000	-.0342776	-.0154323
.nsect_tractor	-.0100219	.0055674	-1.80	0.072	-.0209338	.00089
_cons	-.302114	.1117333	-2.70	0.007	-.5211073	-.0831208
ȷ2v						
_cons	-2.276011	.064979	-35.03	0.000	-2.403368	-2.148654
ȷ2u						
Sex	-1.905681	4.544292	-0.42	0.675	-10.81233	7.000968
Education	1.112196	1.899833	0.59	0.558	-2.611408	4.835799
HH_Size	2.006557	2.154395	0.93	0.352	-2.21598	6.229093
1arital_Status	-6.944684	9.824494	-0.71	0.480	-26.20034	12.31097
.ng_experience	.0397142	.0472406	0.84	0.401	-.0528757	.1323041
'BO_membership	1.508978	2.321907	0.65	0.516	-3.041877	6.059833
Farming_type	1.700698	1.289687	1.32	0.187	-.8270418	4.228438
:ess_to_credit	1.676851	1.389367	1.21	0.227	-1.046259	4.39996
_cons	-7.079447	4.577468	-1.55	0.122	-16.05112	1.892225

```
Stoc. frontier normal/half-normal model          Number of obs      =        109
                                                 Wald chi2(35)      =     103.23
Log likelihood = -43.326836                      Prob > chi2        =     0.0000
```

lnOutput	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lnOutput						
lnLand	-.0599985	.2163944	-0.28	0.782	-.4841238	.3641267
lnLabor	-.0675982	.0304214	-2.22	0.026	-.127223	-.0079733
lnFert	.2427827	.1879091	1.29	0.196	-.1255123	.6110777
lnseeds	.8297912	.7928751	1.05	0.295	-.7242155	2.383798
lnherb	-.1716114	.1552618	-1.11	0.269	-.475919	.1326961
lninsect	.0647283	.1753113	0.37	0.712	-.2788755	.408332
lntractor	-.0357103	.0682439	-0.52	0.601	-.169466	.0980454
lnLand_sq	.0124856	.1775487	0.07	0.944	-.3355034	.3604746
lnLabor_sq	.1019975	.037688	2.71	0.007	.0281303	.1758646
lnFert_sq	.1891972	.192498	0.98	0.326	-.1880919	.5664863
lnseeds_sq	.1412384	.2480345	0.57	0.569	-.3449002	.627377
lnherb_sq	.2698186	.1654046	1.63	0.103	-.0543685	.5940057
lninsect_sq	.507688	.2366307	2.15	0.032	.0439004	.9714756
lntractor_sq	-.0113799	.0144078	-0.79	0.430	-.0396186	.0168588
lnLand_Labor	-.1652884	.1436558	-1.15	0.250	-.4468486	.1162717
lnLand_Fert	.1858521	.0973885	1.91	0.056	-.0050259	.3767301
lnLand_seeds	-.0496971	.2533479	-0.20	0.844	-.5462498	.4468556
lnLand_herb	-.3438265	.1400744	-2.45	0.014	-.6183674	-.0692857
lnLand_insect	.3469809	.1908699	1.82	0.069	-.0271172	.7210789
lnLand_tractor	-.0085799	.0162653	-0.53	0.598	-.0404594	.0232995
lnLabor_Fert	.0467256	.0934555	0.50	0.617	-.1364438	.2298949
lnLabor_seeds	.2488255	.3594201	0.69	0.489	-.4556249	.9532758
lnLabor_herb	.0181726	.111113	0.16	0.870	-.1996049	.2359501
lnLabor_insect	-.1613252	.1203151	-1.34	0.180	-.3971385	.0744881
lnLabor_tractor	.0224344	.0247458	0.91	0.365	-.0260666	.0709353
lnFert_seeds	.0464009	.2864989	0.16	0.871	-.5151265	.6079284
lnFert_herb	-.3007438	.111049	-2.71	0.007	-.5183958	-.0830917
lnFert_insect	.1764145	.1434274	1.23	0.219	-.104698	.4575271
lnFert_tractor	.0373765	.022119	1.69	0.091	-.005976	.080729
lnseeds_herb	-.2949583	.2323242	-1.27	0.204	-.7503054	.1603889
lnseeds_insect	.056203	.308604	0.18	0.855	-.5486498	.6610558
lnseeds_tractor	.0409872	.0277336	1.48	0.139	-.0133696	.0953441
lnherb_insect	-.5283051	.1747811	-3.02	0.003	-.8708698	-.1857404
lnherb_tractor	-.0274161	.0159098	-1.72	0.085	-.0585987	.0037665
linsect_tractor	.0188744	.0176524	1.07	0.285	-.0157237	.0534726
_cons	-.9148582	.4261603	-2.15	0.032	-1.750117	-.0795993
lnsig2v						
_cons	-2.314592	.2681458	-8.63	0.000	-2.840148	-1.789036
lnsig2u						
Sex	2.004962	1.199733	1.67	0.095	-.3464707	4.356395
Education	-.5873331	.7669977	-0.77	0.444	-2.090621	.9159549
HH_Size	-.5231484	2.252183	-0.23	0.816	-4.937346	3.89105
Marital_Status	.3155244	1.929454	0.16	0.870	-3.466137	4.097185
Farming_experience	-.0555327	.0531062	-1.05	0.296	-.159619	.0485536
FBO_membership	1.280556	2.000875	0.64	0.522	-2.641086	5.202198
Farming_type	2.373769	1.034352	2.29	0.022	.346476	4.401062
Access_to_credit	-.2979681	1.179218	-0.25	0.801	-2.609193	2.013257
_cons	-6.373448	3.299622	-1.93	0.053	-12.84059	.0936927
sigma_v	.314335	.0421438			.2416961	.4088046

f. PSM results of the impact of tomato seed variety adoption on technical efficiency

Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
Pectomech						
TE	Unmatched	.931191672	.868604795	.062586876	.012175097	5.14***
	ATT	0.930951316	.861751801	.069199516	.011602608	5.96***
	ATU	.868244883	.926158769	.057913886	.	.
Power_roma						
TE	Unmatched	.81853269	.914596665	-.096063975	.014313518	-6.71***
	ATT	.819627002	.914265606	-.094638604	.014356184	-6.59***
	ATU	.917665745	.819961777	-.097703968	.	.
Techiman						
TE	Unmatched	.817571019	.8986108	-.081039781	.026183293	-3.10***
	ATT	.817571019	.910453273	-.092882254	.059547389	-1.56*
	ATU	.903285504	.833396683	-.06988882	.	.
Joint						
TE	Unmatched	.910908692	.885916009	.024992683	.013067676	1.91
	ATT	.909255261	.888458629	.020796632	.012894017	1.61*
	ATU	.887206387	.909836565	.022630178	.	.
	ATE		.022046943	.	.	

g. Selectivity Correction Based on Multinomial Logit model estimates of Determinants of Welfare of the Selected Improved Tomato Seed Variety

```
Multinomial logistic regression                    Number of obs   =        508
                                                   LR chi2(54)     =     121.33
                                                   Prob > chi2     =     0.0000
Log likelihood = -561.48825                        Pseudo R2       =     0.0975
```

TSV	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Power roma						
Sex	-.4969409	.3331249	-1.49	0.136	-1.149854	.1559718
Age	.0116888	.0151059	0.77	0.439	-.0179182	.0412959
HHSize	-.0027299	.0175723	-0.16	0.877	-.0371708	.0317111
Prim_Educa~n	.308546	1.267599	0.24	0.808	-2.175903	2.792995
Primary_Oc~n	-.567826	.3764302	-1.51	0.131	-1.305616	.1699636
Income_	.322522	.4636209	0.70	0.487	-.5861583	1.231202
Access_to_~e	.4716376	.3354693	1.41	0.160	-.1858701	1.129145
Access_to_~t	-.2641995	.5066842	-0.52	0.602	-1.257282	.7288834
M_insuranc~y	-1.992856	1.095301	-1.82	0.069	-4.139606	.1538943
Years_of_T~n	.0112833	.0220868	0.51	0.609	-.0320061	.0545727
Type_of_fa~g	.3100836	.3150073	0.98	0.325	-.3073194	.9274866
Member_of_~O	.095144	.8288424	0.11	0.909	-1.529357	1.719645
Ryield	.1800443	.102065	1.76	0.078	-.0199993	.380088
RMarket	.1789098	.0936689	1.91	0.056	-.0046778	.3624975
RAccesstos~d	-.0402351	.0866345	-0.46	0.642	-.2100355	.1295654
RResistanc~t	-.0191132	.0816105	-0.23	0.815	-.1790668	.1408403
Rearlymatu~y	-.1234872	.1070834	-1.15	0.249	-.3333667	.0863923
RGoodstora~y	.0259368	.0726286	0.36	0.721	-.1164128	.1682863
_cons	-1.287177	.7982098	-1.61	0.107	-2.85164	.2772852
Techiman						
Sex	-.9571634	.6455392	-1.48	0.138	-2.222397	.3080702
Age	-.0266567	.0249192	-1.07	0.285	-.0754974	.022184
HHSize	-.0259579	.0630846	-0.41	0.681	-.1496015	.0976857
Prim_Educa~n	2.041538	1.384482	1.47	0.140	-.6719967	4.755073
Primary_Oc~n	-.843671	.6661929	-1.27	0.205	-2.149385	.4620432
Income_	2.841981	.5211438	5.45	0.000	1.820558	3.863404
Access_to_~e	1.077374	.5536155	1.95	0.052	-.0076927	2.16244
Access_to_~t	-1.349513	1.022585	-1.32	0.187	-3.353743	.6547162
M_insuranc~y	-1.211007	1.212269	-1.00	0.318	-3.58701	1.164997
Years_of_T~n	.0154503	.0411165	0.38	0.707	-.0651366	.0960372
Type_of_fa~g	-.3227172	.6066414	-0.53	0.595	-1.511712	.8662781
Member_of_~O	1.706404	1.169512	1.46	0.145	-.5857971	3.998606
Ryield	.1282552	.2038013	0.63	0.529	-.271188	.5276984
RMarket	-.0661415	.1639804	-0.40	0.687	-.3875372	.2552541
RAccesstos~d	.0369072	.1566298	0.24	0.814	-.2700815	.3438959
RResistanc~t	.0879027	.1677619	0.52	0.600	-.2409046	.41671
Rearlymatu~y	-.1797805	.2130676	-0.84	0.399	-.5973854	.2378244
RGoodstora~y	-.1411309	.1555763	-0.91	0.364	-.4460549	.163793
_cons	-.1543854	1.342433	-0.12	0.908	-2.785505	2.476734

Pectomech ~a						
Sex	-.0607666	.3147347	-0.19	0.847	-.6776353	.5561021
Age	-.0011311	.0123092	-0.09	0.927	-.0252568	.0229945
HHSize	-.0257613	.0227296	-1.13	0.257	-.0703106	.0187879
Prim_Educa~n	-42.11009	8.88e+08	-0.00	1.000	-1.74e+09	1.74e+09
Primary_Oc~n	.2969442	.3423354	0.87	0.386	-.3740208	.9679093
Income_	.8591833	.3605315	2.38	0.017	.1525545	1.565812
Access_to_~e	.2848125	.2678993	1.06	0.288	-.2402605	.8098855
Access_to_~t	.1226253	.369234	0.33	0.740	-.60106	.8463106
M_insuranc~y	-1.217306	.5505101	-2.21	0.027	-2.296286	-.1383259
Years_of_T~n	.0190301	.0189584	1.00	0.315	-.0181276	.0561878
Type_of_fa~g	.0749407	.2738654	0.27	0.784	-.4618256	.6117069
Member_of_~O	-.3816334	.6605765	-0.58	0.563	-1.67634	.9130727
Ryield	.0360692	.0922207	0.39	0.696	-.1446801	.2168186
RMarket	.0088791	.0809562	0.11	0.913	-.149792	.1675503
RAccesstos~d	-.0233056	.0744141	-0.31	0.754	-.1691546	.1225433
RResistanc~t	-.0204088	.0719965	-0.28	0.777	-.1615194	.1207017
Rearlymatu~y	-.1016784	.0883264	-1.15	0.250	-.2747949	.071438
RGoodstora~y	.0843541	.0631222	1.34	0.181	-.0393631	.2080712
_cons	-.4503802	.6957698	-0.65	0.517	-1.814064	.9133035

(TSV==Pectomech is the base outcome)

Improved tomatoes seed variety adoption, efficiency and welfare of farmers in selected agro-ecological zones of Ghana

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