ESSAYS ON SMALLHOLDER AVOCADO CONTRACT FARMING, GENDER PATTERNS IN LABOR ALLOCATION AND THE EFFECT OF WOMEN'S EMPOWERMENT IN AGRICULTURE ON FOOD SECURITY IN KENYA

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university

Signed.................................... Date.................................

Edna Gardie Johnny

This thesis has been submitted for examination with our approval as university supervisors

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DEDICATION

This thesis is dedicated to God, my parents – the late Joseph P. Johnny and Brima M. Mansaray; Massah M. Johnny, Hajaa Aminata Mansaray and my precious boys Moses B. Massaquoi, Jefferson M. Koijee Jr., Bliss T. Koijee and Emmanuel L. Gokpolu.

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LIST OF ABBREVIATIONS

ACIAR	Australian Centre for International Agricultural Research
AIFSC	Australian International Food Security Center
ASDS	Agriculture Sector Development Strategy
ASGP	Agricultural Sector Gender Policy
A-WEAI	Abbreviated Women's Empowerment in Agriculture Index
CIMMYT	International Maize and Wheat Improvement Center
GAP	Good Agricultural Practice
GDP	Gross Domestic Product
HFIAP	Household Food Insecurity Access Prevalence
HFIAS	Household Food Insecurity Access Scale
IV	Instrumental variable
KIPPRA	Kenya Institute for Public Policy Research and Analysis
NALEP	National Agriculture and Livestock Extension Programme
NASEP	National Agricultural Sector Extension Policy
NPGD	National Policy on Gender and Development
OECD	Organization for Economic Co-operation and Development
OLS	Ordinary Least Squares
PEP	Partnership for Economic Policy
PRESM	Productive Employment in Segment Markets
RESET	Regression Specification Error Test
SRA	Strategy for Revitalizing Agriculture
USAID	United States Aid for International Development
WEAI	Women Empowerment in Agriculture Index

DEFINITION OF OPERATIONAL TERMS

A smallholder avocado contract farmer	One who has at least two or more Hass or *Fuerte* avocado trees cultivated and marketed with support from a local firm or exporter as specified in the contract.
A non-contract smallholder avocado farmer	One who cultivates avocados independently and sells to any available buyer.
Hass	An avocado fruit that has an oval shaped thick skin with a small to medium size seed; they range in weigh from 5 to 12 ounce. Its skin becomes a dark purplish-black when ripe and becomes white green in the middle part of the inner fruit when ready to serve.
Fuerte	An avocado fruit that is a medium-sized, pear shaped fruit with relatively thin smooth and leathery skin that becomes slightly duller when ripe.
Grafting	The process of mixing the tissues of the avocado seedling with those of a producing tree. Grafting ensures that desired characteristics in fruit trees are maintained. This method can also be used to get a Hass variety from a *Fuerte* based tree.
Pruning	The selective removal of dead branches, buds, or roots for the maintenance and health of avocado trees.
Gender	Roles and responsibilities performed by women and men in production activities as expected of them by societies or cultures.

Participation	Involvement of a farmer in avocado production and other economic activities.
Intensity of participation	The amount of time a farmer spends in avocado production.
Women's Empowerment in Agriculture Index (WEAI)	A tool that measures the empowerment, agency, and inclusion of women in the agricultural sector.
Abbreviated Women's Empowerment in Agriculture Index (A-WEAI)	Is a shorter and streamlined version of WEAI.
Food insecurity	A situation when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active and healthy life (FAO, 2008).

ABSTRACT

Avocado has been identified as one of the non-traditional export crops with national and global economic importance in Kenya. Production of the fruit predominantly depends on intra-household division of labor in which gender is the fulcrum around which these divisions occur. Commercialization of avocado through contract farming is a viable way of improving food security and the welfare of majority of smallholders involved in its production in the country. Using data from Central, Western and Eastern Kenya, this thesis investigates smallholder avocado contract farming including determinants and differentials in production and gender patterns in labor allocation. The study further analyzes the effect of women's empowerment on food security.

In essay one; we investigate the determinants of avocado contract farming as well as the differentials in production outcomes between contract and non-contract farmers. The probit model was used to estimate contract participation while the Oaxaca-Blinder decomposition was used to analyze the gap in quality and quantities of avocados harvested and sold by contract and non-contract farmers. Study findings show that the number of *Hass* trees owned, value of assets, hired labor, receiving training in avocado agronomy as well as access to production and marketing information significantly influence participation in avocado contract farming. Gap in production outcomes between participants and non-participants in avocado contract farming is due to both endowment and returns to endowments effects. Our study findings suggest that stimulating smallholder contract farming and closing observed gap in avocado production and marketing require policies that will facilitate training of farmers in good agricultural practices and other support services.

Essay two sought to analyze gender patterns in labor allocation to avocado production and other economic activities as well as the role of avocado contract farming on gender labor allocation. Separate regressions were estimated for males and females using the double hurdle and tobit models. Findings show that exogenous factors such as education, the presence of young children, credit constraints, assets and non-labor income have heterogeneous effects on gendered labor allocation to avocado production. Results further show that while avocado commercialization through contract farming has to some extent altered traditional gender roles in farming, there is still limited participation of women in avocado marketing under contract farming. Hence, interventions aimed at enhancing smallholder avocado production should incorporate mechanisms that will enable women participate at all levels of the avocado value chain.

The objective in essay three was to assess the effect of women's empowerment on food security. Food security in this thesis was proxied by the Household Food Insecurity Access Scale (HFIAS). Food security was operationalized as an index using Principle Component Analysis (PCA) and as categories using the Household Food Insecurity Access Prevalence (HFIAP). The Abbreviated Women's Empowerment in Agriculture Index (A-WEAI) was used as a women's empowerment measure. The effect of WEAI on food security index was analyzed using fractional probit two-stage residual inclusion and control function approaches that controlled for endogeneity, individual heterogeneity and non-linearity of the women's empowerment variable. Instrumental variable ordered probit was used to analyze the effect of A-WEAI on food security categories. Findings show that women's empowerment in decision making on production and asset ownership significantly lowered household food insecurity; and that failure to control for potential endogeneity and non-linearity of the women's empowerment variable produces erroneous results of its effect on food security. The findings imply that creating awareness on the role of women in production decision making and implementing gender inclusive policies that will enable women participate in policy-making at all levels on issues that affect their lives is a necessary step in ensuring food security. Moreover, national and traditional reforms that would enable women own and control productive assets are worthwhile interventions that would yield long-term dividend in food security.

CHAPTER ONE: INTRODUCTION

1.1 Background to the study

Agriculture is a key sector in Kenya's economy, contributing 32.6 percent to Gross Domestic Product (GDP). It also contributes about 27 per cent indirectly through the manufacturing and other service-related sectors (KIPPRA, 2017). The 10 percent annual economic growth target of Kenyan vision 2030 is pegged to commercialization of agriculture and food security among others. Agricultural activities are dominated by smallholder farmers most of whom produce on farms averaging 0.2-3 hectares (Republic of Kenya, 2010). Production critically depends on intra-household division of labor in which gender is the fulcrum around which these divisions occurs.

Women play a significant role in commercial as well as subsistence food production. They contribute 60 to 80 percent of labor in households and in agricultural production (Republic of Kenya, 2010). Despite the critical and transformative role of women in agricultural growth, they are faced with persistent challenges and economic constraints that further limit their inclusion in agriculture. Unlike their male counterparts, women farmers are less likely to have access to credit, extension services and be endowed with resources such as land (Republic of Kenya, 2010). Moreover, with the trend in agriculture commercialization and migration of men in search of other off-farm economic opportunities, women are in most cases left to perform roles previously performed by men (Kiriti and Tisdell, 2002).

The agricultural sector consists of six subsectors— food crops, livestock, fisheries and forestry industrial crops and horticulture. Horticulture is the largest and most dynamic sub-sector, contributing 36 percent of the agricultural GDP (RSA, 2015). Avocado has become one of the major exports and foreign exchange earner contributing to growth of the horticulture fruit sub-sector. Some years back, the fruit was produced mostly for local consumption. Today, production and market trends have significantly changed due to increasing local and global demand for the fruit. The price of Kenyan avocados in Europe is about three times the price in the local market (ITC, 2016). About 85 percent of avocados exported from Kenya are produced by smallholders (HCD, 2010). The volumes of exports have been increasing steadily over the years. Except for a slight decrease in 2013, avocados recoded the highest export volume compared to mango and passion fruit between 2011 and 2015 (HCD, 2016) –See Figure 1. The decrease in this period was attributed to decrease in market demand due to exportation of immature fruits.

Kenya is the fifth largest avocado exporter to the European Union after Peru, Israel, Mexico and South Africa. Comparatively, the country has a unique niche in terms of production season than many other avocado exporting countries. The country has an additional advantage of more competitive shipping costs than its African competitor - South Africa (Knopp and Smarzik, 2008). Besides its monetary contribution, avocado has high nutritional value that boosts nutrition security. Increase in the demand for avocado in pharmaceutical and cosmetic industries also provide added opportunity for the expansion of avocado production. About 70% of the fruit is grown in Central and Eastern regions, with Central region being the leading producer. The main varieties of avocado grown in Kenya are *Hass* (20%) and *Fuerte* (80%) for export market and *Pueble*, *Duke* and *G6* for the domestic market (HCD, 2010).

Although, avocado exports are increasing, *Fuete* which dominates production accounts for only 10 percent of exports while *Hass* which is the preferred export variety accounts for 20 percent (HCD, 2014). The imbalance between the dominance of *Fuerte* variety and market preference for *Hass* presents a challenge for avocado sector competitiveness. In addition, market demand for GLOBALGAP certification[1] especially in fresh produce market further exacerbates the constraints of resource poor women farmers and serves as a barrier to smallholder agriculture commercialization as a whole. The government in collaboration with private sector partners such as USAID and Embassy of the Kingdom of the Netherlands have implemented several programs to improve avocado production and export performance of the sector. The projects provided farmers with quality seedlings on credit, trained them in Good Agricultural Practice (GAP) and linked them through formal contract to exporters. These projects noted that with the new global gap certification requirement, marketing constraints and other production costs, the possible way

[1] GLOBALGAP is a private sector body that sets voluntary certification standards and procedures for good agricultural practices (HCD, 2014)

for farmers to benefit from production and for the country to remain competitive in the global market is through contract farming (Solidaridad, et al., 2016).

Given the overwhelming dominance of smallholder farmers in the sector and the significant role of women, exploiting potential synergies between policies and strategies that can boost smallholder market participation and enhance women's empowerment in agriculture is critical to agriculture sector growth and food security. Against this backdrop, the Kenyan government has adopted long term policy frameworks such as the Strategy for Revitalizing Agriculture (Republic of Kenya, 2004), Vision 2030 (Republic of Kenya, 2008) and the Agriculture Sector Development Strategy (Republic of Kenya, 2010). In addition, the National Agricultural Sector Extension Policy (NASEP) was enacted in 2012 to improve extension system delivery. The Agriculture, Fisheries and Food Act 2013 and Crops Act of 2013 were also developed to enhance productivity and market potential of farmers. Moreover, Sectional paper No. 1 of 2017 on land use Policy was developed to address critical land issues like land rights that affects agriculture production. Other flagship projects such as fertilizer cost reduction strategy, grain drying and storage facilities were also implemented during second medium term period (2013-2017) to boost agricultural production (Republic of Kenya 2017).

Several policy measures have also been taken to address gender imbalances and constraints of women in agriculture. The Constitution of Kenya, 2010 provides a framework for addressing gender inequality. Other interventions such as the National Policy on Gender and Development (Republic of Kenya, 2000) and the Agricultural Sector Gender Policy (2009) were developed to improve institutional transformation and gender-responsive programing in the agricultural sector. In addition, the government launched the Women Enterprise Fund in 2007 to provide accessible and affordable means of credit for women who could not access credit from formal institutions.

Figure 1.1: Selected fruits export volumes (Tons) by Kenya 2011-2015

Source: Agriculture and Food Authority (AFA), Horticulture Crops Directorate (HCD, 2016)

1.2 Statement of the problem

In realization of Kenya's poverty reduction and food security goals, several policies have been implemented to make the agriculture sector sustainable, commercially oriented and competitive. Despite these policy measures and strategic formulations, agriculture is still mired with low incomes and food insecurity. In a potential growth sector like avocado, majority of the farmers are not realizing benefits from production due to rampant crop disease, perishability of the fruit, limited market access and marketing information. About 94 percent of farmers sell their avocado to middlemen or brokers who offer relatively low price for the fruit (Omolo et al., 2011). Besides the low price, farmers also experience loss in fruit quality due to poor harvesting and handling techniques which damage the crop. Moreover, Kenya's inability to adjust her production profile to the evolving global demand for *Hass* variety poses a threat for maintaining her market share (ITC, 2016).

Most of these systematic challenges experienced by avocado farmers could be addressed through contract farming. With the various government policy measures, support system, coupled with the pilot market linkage project implemented by private partners that demonstrated the beneficial effects of contract farming, one expects to see more smallholder participation in avocado contract farming. This is however not the case. The high percentage of farmers losing out on the benefits from avocado as indicated by Omolo et al., (2011), shows that interventions to ensure farmer's linkage to market through contract farming have not yielded the expected fruits. This suggests that research should go beyond investigating factors influencing participation and non-participation to include underlying differences between contract and non-contract farmers. Such analysis would provide information on potential factors that tend to deter farmers from participation in contract farming.

Systematic documentation of these differences is still limited in the existing literature. Descriptive analysis by Cahyadi and Waibel, (2013) showed that oil palm contract farmers in Indonesia were different from non-contract farmers in several performance indicators. The descriptive analysis however poses a problem for generalization. While considerable literature has grown around investigating factors that influence contract participation incentive, Eaton and Shephard (2001) indicated that contracts differ by typology and crop type, thus; this diversity raises the need to investigate incentives for participation in avocado contract farming. This study offers important insights in contract farming literature by not only assessing factors influencing avocado contract farming but also providing quantifiable estimates of differentials in production outcomes between contract and non-contract avocado farmers.

Moreover, increasing demand and commercialization of avocado is expected to increase women's labor allocation to production of the fruit. With sufficient evidence of changes in intra-household labour allocation and gendered crop production (Eerdewijk and Danielsen, 2015; Kiriti and Tisdell, 2002), analysis of gender-based heterogeneity in production could provide understanding of gender specific constraints that could lower women's return to labor in avocado production (Ilahi, 2000). Previous studies on avocado crop (Omolo et al., 2011; Oduol et al., 2014; Gyau et al., 2016) have mainly focused on exploring interlinkages within the avocado value chain, while investigation of how structural changes in household labor allocation might hamper avocado production is neglected. Failure to account for these gender specific roles and constraints in avocado production could lead to inefficiencies that could dampen the growth potential of the fruit and the sector as a whole. This study addresses this gap by providing measurable evidence of gender patterns in labor allocation to avocado production.

Furthermore, amidst concerted strategies and policy interventions, Kenya is struggling with food insecurity; about 2.6 million people are food insecure (Republic of Kenya, 2018). Although exogenous shocks such as persistent drought have worsened the food insecurity situation, perennial problem of food insecurity have been attributed to limited value addition, low agriculture productivity and high post-harvest losses (KIPPRA, 2017). In addition, women farmers who play a major role in agriculture are faced with multiple constraints that limit their productivity. According to the National Agriculture and Livestock Extension Programme (NALEP, 2009), about 95 of women working in the agricultural sector simply farm the land and graze livestock but have minimal control in terms of decisions on farming inputs and marketing, credit access or how income from farming are spent. Women also have low asset ownership and face unequal division of labor. The report further iterated that women farmer's needs are not clearly captured or prioritized by government policies that dictate productivity in the agricultural sector particularly in the extension services.

Evidence from development literature shows that, addressing vulnerabilities of women farmers do not only drive up their productivity and food security but also succeed in benefiting them and the community as a whole (Doss, 2017). Thus, the social rate of return from investing in women farmers is much higher than other development investment (Doss, 2017). Given the critical role of rural women in ensuring food availability, access, and utilization, neglecting the needs of women farmers will undermine long run food and nutrition security achievement (ADB, 2013). Several studies using the newly developed women's empowerment in agriculture index (WEAI) demonstrated that women's empowerment in agriculture have significant links to food security outcomes (Srabon et al., 2014; Malapit and Quisumbing, 2015). Similarly, Seymour et al., (2016) and Diiro et al., (2018) showed that women's empowerment in agriculture is positively correlated with increased productivity and technology adoption in Kenya.

Although the studies of Malapit and Quisumbing, (2015) and Srabon et al., (2014) are based on food security access utilization component, Sen (1981) argues that food access is the most integral part of food security. According to Sen, poor people may starve not because of food unavailability but because they lack entitlement. This assertion has increased the popularity of experience-based measure of food security that captures both the physical and social aspects of food security which other measures do not (Jones et al., 2013). On the other hand, the studies by Seymour et al., (2016) and Diiro et al., (2018) analyzed the effect of women's empowerment in agriculture on technology adoption and agricultural productivity but did not explicitly assess food security.

Kabuga et al., (2014) investigated the access component of food security using the experience-based measure (HFIAS). Their study did not however investigate the relationship between women's empowerment in agriculture and household food security. Our study contributes to the literature by investigating the effect of women's empowerment in agriculture on household food security.

1.3 Research questions

The thesis addresses the following questions:

i. What explains smallholder avocado contract farming and differentials in production outcomes between contract and non-contract avocado farmers in Kenya?
ii. What influences gender patterns in labor allocation to avocado production in Kenya?
iii. What is the effect of women's empowerment on food security in Kenya?

1.4 Purpose and objectives of the study

The study assesses smallholder avocado contract farming, gender patterns in labor allocation and the effect of women's empowerment on food security in Kenya. The specific objectives include:

i) To investigate the determinants of smallholder avocado contract farming as well as differentials in production outcomes between contract and non-contract avocado farmers in Kenya.
ii) To analyze gender patterns in labor allocation to avocado production and other economic activities in Kenya.
iii) And to assess the effect of women's empowerment in agriculture on food security in Kenya.

1.5 Relevant to literature

This thesis is well anchored on the relevant literature related to the three key research issues: the determinants of smallholder avocado contract farming and differentials in production outcomes between contract and non-contract avocado farmers; gender patterns in labor allocation; and the effect of women's empowerment in agriculture on food security.

Contract farming is one of the agricultural innovations that provide opportunity for market linkage of resource constrained smallholder farmers. The rationale for contract farming as an institutional response to market failure is based on the Transaction Cost Theory from the New Institutional Economics school of thought (Coase, 1937). The central tenet of this theory is that every market transaction generates cost caused by information asymmetry. The fact that information is not costless has important implications for smallholders who need reliable information on markets and potential customers, improved production technology and methods. While literature underscores the importance of contract farming as a tool for strengthening smallholder market access, the pervasive market and structural failures under which production and market tractions occur especially in developing countries suggests that analyzing factors that influence avocado contract farming requires incorporation of transaction costs into an agricultural household model framework (Key et al., 2000).

Review of contract farming literature shows that contract farming differs by crop type and contract agreement. This diversity has increased the focus of research in investigating smallholder farmer’s contract participation incentives for various crops. Econometric analysis of the determinants of contract farming is mostly based on probit and logit models since participation is dichotomous. Suggestive evidence from these studies show that farmer’s demographic and household characteristics as well as other economic and social factors are important correlates of contract farming (Warning and Key, 2002; Man and Nawi, 2010; Wainaina et al., 2012; Mwambi et al., 2013).

Furthermore, studies on contract farming showing differentials in outcomes such as use of improved agricultural practices and yield by contract and non-contract farmers are most often purely comparative analyses (Tatlidil and Akturk, (2004) and Cahyadi and Waibel, 2013). While these analyses provide important information on differences in production outcomes between the two groups, the results do not provide rigorous quantifiable evidence of factors that generated differences in these outcomes of interest that could guide policy making on contract farming. This thesis contributes to the literature on contract farming by employing decomposition technique that provides an explanation in the statistical sense of differences in production outcomes between contract and non-contract avocado farmers.

Gender patterns in labor allocation to agricultural production and other economic activities have generated growing interest in developing countries because of the policy implications in terms of poverty alleviation and food security. Becker's (1962) time allocation theory anchored on the unitary household model is the dominant framework for modelling household level analysis of production and labor allocation. According to this theory, women's disadvantaged position in the labor market can be attributed to the low valuation of their human capital. Available literature however suggests that institutional failures, inequalities in opportunities and social roles that cannot be explained by economic variables tend to perpetuate binding constraints for women (Buvinić, and Furst-Nichols, 2016; Doss, 2014).

Different approaches have been used in empirical studies to analyze gender differentials in labor allocation to crop production. Some studies have explained these differences through descriptive analysis or simple linear regression (Eerdewijk and Danielsen 2015; Kiriti and Tisdell, 2002). Others studies have used the standard Tobit model to handle data censoring which occurs in labor allocation decision as a result of the inevitability of a non-negligible sample of non-participants (Palacios-Lopez et al., 2015; Fafchamps and Quisumbing, 2003; Ilahi, 2001). The key underlying assumption for the Tobit specification is that farmers with a positive labor supply have unconstrained access to time used and also non-participation in an activity is due to a rational decision made by the farmer. In situations where farmers allocate labor to various economic activities, or where participation may be due to division of responsibilities, this assumption is untenable. The Double Hurdle (DH) model formulated by Cragg (1971) is an improvement of the Tobit model. It allows for the modelling of labor allocation as a two stage decision processes. The DH has wide applicability in consumption studies (Jones (1989, 1992), and off-farm labor supply studies (Woldehannaet al., 2000 and Matshe and Young, 2004)

Results from these studies indicate that males allocate more labor time to income generating activities while females were in charge of home production activities (Fafchamps and Quisumbing, 2003; Ilahi, 2001). Some studies documented that modernization of agriculture, migration of males from farming households and agricultural commercialization have altered traditional gender roles in production (Eerdewijk and Danielsen, 2015; Fischer and Qaim, 2012). Although studies of gender and labor allocation to production are increasingly the focus of agricultural development agenda in developing countries, this phenomenon has not been well documented especially for a crop like avocado which is of commercial interest in Kenya. Moreover, the generalization of descriptive analysis is problematic while the Tobit model does not provide the mechanism for analyzing factors that constrain time use by gender. This thesis addresses the information gap by assessing gender patterns in avocado production and other economic activities as a two stage procedure of participation and intensity of time use.

Food security is a fundamental issue that is often highlighted in policy discussions in developing countries and the global community. The theoretical framework of the unitary model had been the basic tool for modelling household production. A number of studies however indicate that although the unitary model is relevant in several perspectives, it is not adequate to analyze women's bargaining power within the household which are likely to affect several outcomes (Chiappori, 1988; Lundberg and Pollak, 1993). As such, empirical research aimed at issues of intra-household decision-making and food security is now anchored on bargaining theories. Literature on food security shows that estimation of household food security level often presents challenges in terms of choice and measurement of the selected indicators due to the multifaceted nature of food security. In recent years, fundamental advances have been made to obtain a direct measure of household food insecurity using scales based on the perception or experience reported by the affected individuals.

Studies using the HFIAS experience based measure of food security analyzed food security as either binary, categorical variable or as an index. In that case, binary, ordered and linear models are used. Results from these studies indicated that household and farm characteristics as well as socio-economic indicators are significant predictors of food security (Kimani-Murage et al., 2014; Murendo and Wollni, 2016; Kabuga et al., 2014). While these studies are based on experience measure of household food security, information on the role of women's empowerment which is critically linked to food security is missing. Research on the role of women's empowerment in agriculture using objective measures of food security have mostly relied on two stage-least squares instrumental variable technique due to the endogeneity of the women's empowerment variable. These studies demonstrated that women's empowerment in agriculture is significantly related to food security outcomes (Srabon et al., 2014; Malapit et al., 2013; Malapit and

Quisumbing, 2015). Although these studies considered the role of women in food security, they have not been aligned towards subjective measures of food security. This thesis bridges this gap in information by examining the effect of women's empowerment in agriculture (WEAI) on food security using the HFIAS subjective measure of food security.

1.6 Conceptual framework

Avocado contract farming, gender patterns in labor allocation to various activities, and the effect of women's empowerment on food security are related in several respects. While they are driven by more or less the same conditioning factors, they have important implications on smallholder production and welfare. Avocado production critically depends on family labor, thus, increase in demand for the fruit heightens household labor demand. Labor allocation to avocado contract farming provides employment opportunities and income. The income and employment effects of avocado production enhance household food security (OECD, 2008) and increases women's bargaining power to make decisions on the use of income, farm production, own assets, make credit decisions and enable them to become active members of groups in their community. Women's empowerment in agriculture in return increases household food security (Sraboni et al., 2014).

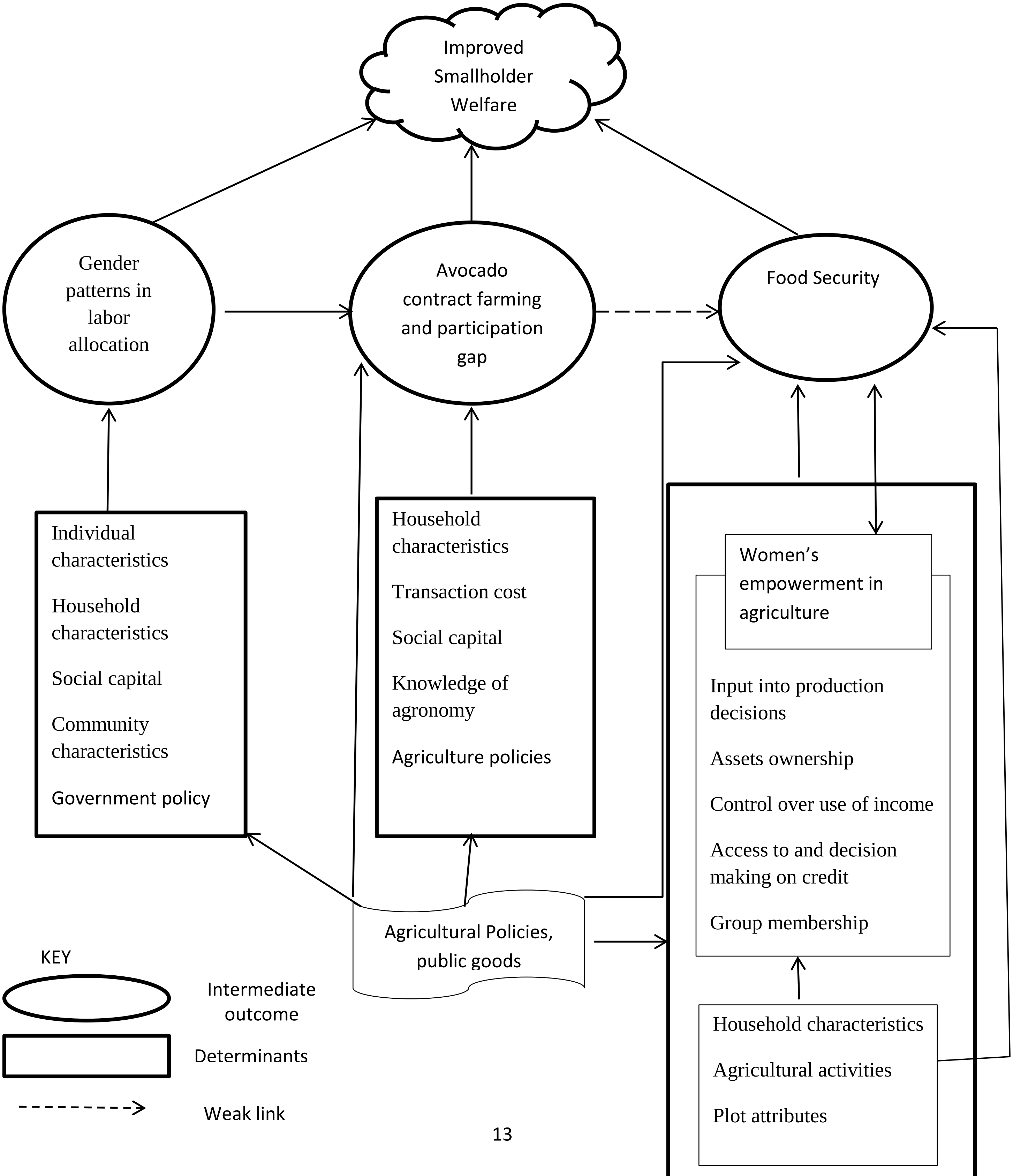
Other factors such as household characteristics, agricultural activities and plot attributes also influence food security. The linkages characterizing avocado contract farming coupled with enabling policy environment suggests that investigating factors that influence smallholder participation in avocado contract farming, gender patterns in labor allocation to avocado production and the effect of women's empowerment on food security, could provide pathways of stimulating a virtuous cycle of improving smallholder welfare. Indeed there are feedback effects between development outcomes and women's empowerment in agriculture (Sraboni et al., 2014).

Government agricultural policies and the provision of public goods play a critical role in both the determinants and outcome variables to enhancing smallholder welfare. Governments provision of public goods and services such as roads to communities reduce market transactions cost and also enable farmers who are in remote areas to access market and participate in the labor market.

Avocado farming predominantly depends on both male and female household labor. The level of participation and time spent in this activity is influenced by exogenous factors such as individual and household characteristics, social capital and community characteristics.

Similarly, government policies and interventions provide an enabling environment for private sector involvement in contract farming, women's empowerment and food security. Private sector intervention through contract farming mitigates challenges faced by smallholder farmers in input and output markets. Prowse (2012) argues that with the systematic market failure and global market demand for gap certification especially in fresh produce export; contract farming is an intervention that addresses the various systematic challenges faced by smallholder avocado farmers. Factors such as household characteristics, transaction costs, social capital and farmer's agronomy knowledge determines their participation in contract farming.

Figure 1.2: Links between avocado contract farming, gendered labor allocation, women empowerment and food security



Source: Author's compilation

1.7 Methodological approaches

This thesis uses innovative methods to achieve the objectives of the study. Based on the literature and the conceptual framework, the theoretical framework for investigating the determinants of avocado contract farming and differentials in production outcomes is based on the non-separable agricultural household model which incorporates transaction cost into the household utility maximization model (Singh et al., 1986). The framework enables us to explore the effect of training in avocado agronomy, among other factors, on smallholder participation in avocado contract farming as well as differentials in production outcomes between contract and non-contract farmers.

Empirically, the probit model was used to analyze participation incentives. The model has the attraction of being associated with a standard normal distribution which is motivated by the central limit theory. The Oaxaca-Blinder (0-B) decomposition model was used to assess differentials in production outcomes between contract and non-contract avocado farmers. The model is widely used to explain the gap in the means of an outcome variable between two groups. The O-B methodology has however been criticized on grounds of not addressing the index number problem (i.e. the discrimination term or gap is not invariant to the reference group which is arbitrarily chosen by the researcher) - (Cotton, 1988). It is also criticized for not taking selectivity into account (Madden, 1999).

Neumark, (1988), Oaxaca and Ransom, (1994) and Reimers (1983) suggested solutions to the index number problem although their approaches vary. Oaxaca and Ransom, 1999) and Jann (2008) also demonstrated that with the threefold Oaxaca-Blinder decomposition, the overall decomposition and the separately estimated endowment and coefficient effects are invariant with respect to the choice of left-out reference groups. In furtherance to these, Neuman and Oaxaca (2004) also showed that the decomposition can be adjusted to account for selectivity. The three threefold Oaxaca-Blinder decomposition that accounts for selection bias is used in this thesis to delineate gap in production outcomes between contract and non-contract avocado farmers.

In analyzing gender patterns in labor allocation to avocado production and other economic activities, an agricultural household model that incorporates labor supply decision of an agricultural household into a single unit (Singh et. al., 1986) is used. This model provides a framework for assessing the effect of resource constraint on the opportunity cost of male and female labor allocation. The double hurdle model (DH) was used to empirically analyze gender patterns in labor allocation decisions in avocado production and other economic activities. The DH is designed to explain individual labor allocation as a two-step process of participation decision (first hurdle) and the level of time use decision (second hurdle).

The model specification depends on the distributional assumption made regarding the error terms in the two hurdles. In earlier version of the DH model, the two stochastic processes are assumed to be independent (Atkinson, 1984; Reynolds, 1990). Later applications of DH model are modified to include dependence between the two errors, since in most cases, participation affects time use decisions (e.g. Blaylock and Blisard, 1992; Blundell and Meghir, 1987; Jones, 1989, 1992; Lee and Maddala, 1985). The modified version of the DH model with bivariate decisions has gained popularity in empirical studies. Smith (2003) however criticized the bivariate double hurdle model on grounds that there is little statistical information to support the estimation of dependency, even when dependency is truly present. Gao et al., (1995) argued that if the assumption of homoscedastic, normally-distributed, errors in the dependency assumption is violated then maximum likelihood parameter estimates are inconsistent. Hence the probable reason some studies were unable to support the existence of a dependency parameter. Since the decision of farmers to participate in avocado production and other economic activities is likely to affect the intensity of time use, we adopted a DH model with dependency and we also transformed dependent variables to ensure a normal distribution.

Finally, to analyze the effect of women's empowerment in agriculture on food security, we anchored our study on the Nash cooperative bargaining model which provides the framework for understanding the relationship between women's decision making on production and household food security. Women's empowerment in agriculture indicators were incorporated into the utility function as a measure of women's bargaining power. Based on this framework, we tested the effect of women's empowerment (WEAI) on food security (HFIAS). The HFIAS data which was collected according to the Coates et al., (2007) module was aggregated into a composite index using principle component analysis (PCA). The WEAI index was computed using methodology proposed by (Alkire et al., 2013; Malapit et al., 2017). Due to endogeneity and non-linearity of the WEAI variable, instrumental variable estimation using the two-stage residual inclusion and control function approaches that offer strong grounds for causal effect of WEAI on food security were used. Instrumental variable (IV) ordered probit model was used to assess the effect of women's empowerment on household food insecurity categories. In the absence of an appropriate external instrument, statistical methods that are robust for generating relevant instruments through heteroscedastic errors (Lewbel, 2007), was used to analyze the effect of individual women's empowerment variables on food security.

1.8 Data needs, types and sources

This study used primary data. Essay one and two used household data collected by the Productive Employment in Segment Markets of Fresh Produce (PRESM) project in 2015/16. The PRESM project was supported by the Netherlands Organization for Scientific Research and WOTRO Science for Global Developments. The project was implemented and led by Partnership for Economic Policy (PEP) in collaboration with the VU-University of Amsterdam and Amsterdam Institute for Global Health and Development (AIGHD), University of Nairobi, Fresh Produce Exporters Association of Kenya (FPEAK), Grupo de Análisis para el Desarrollo (GRADE) and PRIME-ITC (coordinated by LEI Wageningen UR). Essay three is based on cross sectional data collected by the Adoption Pathways Project (APP). The project was funded by the Australian International Food Security Center (AIFSC) and Australian Centre for International Agricultural Research (ACIAR). It was implemented by the International Maize and Wheat Improvement Center (CIMMYT) in Ethiopia, Kenya, Tanzania, Malawi, and Mozambique. The Kenyan data was used for our study.

1.9 Study area and sampling procedure

The PRESM project collected detailed household data on: (i) demographic and socioeconomic characteristics of farmers; (ii) avocado production practices, including contractual arrangements, marketing, farm labor allocation, incomes and utilization and labor returns to avocado among other variables of interest. The data was collected from Murang'a County of Central Kenya in November-December 2015.

A multistage sampling approach was used to select the county, sub-county, villages and households. In the first stage, Murang'a County in Central region of Kenya was purposefully selected from 47 counties because it is the main avocado producing county in Kenya. Kandara sub-county was then selected in the second stage from seven sub-counties of Murang'a County. This sub-county was selected because it is the main avocado producing sub-county in Muranga and the County government has thrown its weight behind avocado production. Besides, the County has experienced substantial expansion in avocado production over the previous ten years in both volume and exports and therefore was found to provide a setting for an interesting case study to analyze the implications for rural development.

Three main household groups based on their participation status regarding avocado marketing contracts, were selected in the third stage. The first group comprised of farmers involved in contract farming; the second group comprised of farmers who had new contractual arrangements with Small and Medium Enterprises from the 2016 avocado season; the third group comprised of farmers without contracts who sold their avocado to middlemen or brokers. In the final stage, a sample size of 790 was randomly selected from a sampling frame provided by the Kandara sub-county agricultural office. The sample consisted of 266 contract farmers; those who had just signed contracts consisted of four farmer groups, each consisting of 50-60 farmers. From this group, 30-40 farmers were randomly sampled from each farmer group totaling up to 144 farmers. A total of 380 farmers without contracts were also randomly sampled making the total sample for our study 790.

The survey instruments consisted of two questionnaires. A household questionnaire was administered to all households in the sample while a Farmers' Organization (FO) instrument was administered to all households engaged in avocado framers group. The household questionnaire collected information on the number of mature avocado trees owned, household demographic composition and resources, various income sources and a variety of household contextual characteristics. Information was also collected on avocado production and marketing, knowledge of avocado farmers' agronomy, harvesting, marketing, access to credit and banking. The respondents were also asked to rate their trust in other people with regards to reliability, meeting their interests and fairness on a scale of 1 to 5.

Data on labor allocation to avocado and other agricultural production activities, wage employment and non-farm self-employment was collected through a year recall. Household heads were asked about the total amount of time spent by each adult member 15 years and above in land preparation (which includes planting, grafting, pruning etc.), weeding and pests control, threshing/winnowing and marketing in household crop enterprises such as avocado, maize, beans, banana, coffee, tea and other crops grown by households. For wage employment and marketing, data was collected on the amount of time spent by adult members in physical, management and marketing activities. This was complemented by further probing as to the number of days per week and the average number of hours per day worked by each member on a particular activity. The working time was capped at 8 hours per day and 6 days per week. The total labor days worked for the year was then obtained by multiplying the number of hours worked by the number of days worked times 12 months.

The farmers' organization questionnaire collected information on general FO characteristics; FO support (external and internal) and linkages; tension containment tool; and capacity performance index. Farmers' organization questionnaire discussions with avocado farmers in most of the farmer groups complemented the household survey. The farmers were interviewed with a structured questionnaire.

The Adoption Pathways Project (APP) collected both household level and individual detailed gender disaggregated data in September-November 2013 for approximately 540 households from three counties in Eastern Kenya – Tharaka Nithi, Embu, and Meru and two counties in Western Kenya – Bungoma and Siaya. Two sets of semi-structured questionnaires were administered to each household i.e. a household level questionnaire administered to both wife and husband whenever it was possible, and an individual level questionnaire administered to husband and wife separately but simultaneously to avoid response contamination. Key socio-economic data collected included: age, gender and education level of household heads; family size; household wealth indicators (livestock, farm size, and other physical assets); social networks, including membership of avocado farmers' organizations; meeting attendance, the number of traders the respondent knew in his/her vicinity.

Information at the village level was also collected including visit of extension officers, distance to the nearest market, water source, proportion of total annual labor contribution by females in the household to plowing, planting, weeding, harvesting and threshing) for all crops produced by the household. The survey instrument also collected information on household food security using the Household Food Insecurity Access Scale (HFIAS) module which is an updated version of the United States Household Food Security Survey Module widely used in developing country context (see appendix 3, Table A10 for food security questions). The individual level information collected relates to four of the five domains of empowerment specified in the Women Empowerment in Agriculture index (WEAI). These domains include production, resources, income, and leadership, using questions adapted from the standard WEAI questionnaire (Alkire et al., 2013).

1.10 Contribution of the thesis

Overcoming smallholder commercialization barriers is largely considered critical to any long-term development strategy to reduce poverty and hunger. This thesis contributes towards the design of better agricultural policies that could improve smallholder market linkage and food security in a number of ways. First, the study provides empirical evidence from Kenya on smallholder avocado contract farming through an in-depth investigation of the determinants and differentials in production outcomes. Avocado production has market, economic, and nutritional potential to stimulate rural development and improve smallholder welfare. However due to the fruit's perishability and market demand for traceability and certification, profitability from production depends highly on contract farming. Although there is a considerable amount of literature on contract farming, there is no evidence of rigorous gap analysis in various production indicators for contract and non-contract farmers for the avocado value chain.

Second, the study contributes to gender, agriculture and labor literature empirically by analyzing gender patterns in labor allocation to avocado production in Kenya under contract and noncontract scenarios as well as to other economic activities. While there are some previous studies on avocado production in Kenya (Oduol et al., 2014; Gyau et al., 2016; Omolo et al., 2011), little is known on how various exogenous factors affect gender roles in avocado production and trade-offs made with other economic activities. We also estimate participation and intensity of time use decisions as a two stage decision processes for males and females. Previous studies (Fafchamps and Quisumbing, 2003; Schindler 2008; Palacios-Lopez et al., 2015) documented gender patterns in time allocation using models that assumed the same exogenous factors influenced both participation and intensity of time use decisions. This is a rather strong and unappealing assumption which does not hold true in most cases. This study provides evidence that the two decisions are separate and can be influenced by different factors. Other studies (Kiriti and Tisdell 2002; Eerdewijk and Danielsen 2015) used multiple regression and descriptive analysis which only provides information on participation and not the intensity of time use.

Thirdly, our study contributes to gender and food security as well as agricultural literature by providing empirical analysis of the relationship between women's empowerment and food security using a subjective measure of food security. Although other studies have assessed the impact of women's empowerment on food security (Malapit and Quisumbing, 2015 and Srabon et al., 2014), the use of subjective measure provides a better assessment of food security since it captures both the physical and psychological aspects of food insecurity (Deaton, 2010). Using women's empowerment in agriculture A-WEAI methodology, we provide evidence of domains in which rural women are disempowered and channels through which women's empowerment affects food security.

Lastly, the study incorporates econometric strategies that control for potential endogeneity and non-linearity of the women's empowerment variable. We demonstrate that failing to control for endogeneity may lead to biased conclusions of the effect of women's empowerment on food security. We also show that not correctly accounting for non-linearity of the empowerment variable may lead to overestimating the true impact of women's empowerment on food security. Furthermore, we illustrate that in the absence of relevant instruments for the individual women's empowerment variables, generating instruments through heteroscedastic errors is a robust alternative that can be exploited for model identification.

1.11 Organization of the thesis

The thesis is organized into five chapters. Chapter one is the introduction that outlines the motivation of the thesis, the aim, relevance to literature, conceptual framework, an overview of the methodological approaches, data and contribution of the thesis. Chapter two presents the first essay and addresses the first objective of the thesis. Chapter three presents the second essay and addresses the second objective. Chapter four presents the third essay and addresses the third objective. Finally, chapter five presents summary, conclusions and policy recommendations.

CHAPTER TWO: SMALLHOLDER AVOCADO CONTRACT FARMING IN KENYA: DETERMINANTS AND DIFFERENTIALS IN PRODUCTION OUTCOMES

2.1 Introduction

Following liberalization of agricultural markets in the 1970's, contract farming developed as the mechanism through which smallholders could be integrated into rural development initiatives. Since then, research has been focused on investigating the two facets of determinants and welfare impact of smallholder participation in contract farming. There have been divergent views on the welfare impact of contract farming with proponents arguing that contract farming ensures self-sustained development owing to its potential in addressing several market constraints simultaneously (Bolwig et al., 2009; Prowse, 2012), while those with contrary view are skeptical of contract manipulation by large agribusiness firms to the detriment of smallholder farmers due to the unequal bargaining power and marginalization of women farmers with limited or no access to land (Guo et al., 2005).

Notwithstanding these concerns, there is an upward trend in contract farming schemes in developing economies. This upsurge can be attributed to demand and supply side factors. Demand side factors include population growth, urbanization and rising income which has propelled changes in consumer taste and food preferences for a more balanced diet. These changes have also increased the demand for fresh fruits and vegetables. Supply side factors on the other hand encompass political and economic aspirations of African governments to develop backward linkages towards smallholder agricultural commercialization especially in non-traditional exports like fruits and vegetables (Da Silva, 2005).

Avocado production in Kenya presents an interesting example of non-traditional exports that has economic and market potential that could be used to diversify the rural agriculture sector and improve the welfare of farmers. The rising global demand for the fruit underscores a vital opportunity for smallholder farmers to improve yields and exports to meet the growing market demand. The profitability of avocado exports and remaining afloat in the competitive global market however depends on the quality of fruits export. Buyers in the export market prefer a clean and sound quality avocado that is free from damage and skin defects (HCD, 2016).

The increase in demand for fresh products also comes at an economic cost of stringent rules of certification to ensure food quality and consumers safety. Fruits that meet quality and other requirements fetch premium prices while those that do not meet the requirements are either blocked from entering the European market or the fruits remain on the shelves unsold if they managed to enter the market (HCD, 2016). These rules and regulations have tightened the value chain and increased transaction costs, both factors which threaten to exclude smallholders from the export chain. Most governments have responded to these changes by designing policies and strategies to remove blockages that constrain smallholder productivity and competitiveness.

In Kenya for instance, the Kenya National Agribusiness Strategy (KNAS of 2012) was formulated to identify and remove bottlenecks that limit or threaten to exclude the vast majority of smallholder farmers from the agricultural value chain (Republic of Kenya, 2012). The strategy proposes how the agribusiness sector can enhance the realization of Kenya's vision 2030 annual economic growth rates of 10 percent from 2012. Contract farming has been identified as a pivotal component of the agribusiness sector strategy for value addition of agricultural products and the means of making the elusive dreams of smallholder entry into the global market a reality.

Contract farming can be defined as an oral or written agreement between the exporter and the farmer specifying conditions of production and marketing (Rehber, 2007). In this specific case, a smallholder avocado contract farmer is one who has at least two or more *Hass* or *F*uerte avocado trees cultivated and marketed with support measures from local firms or exporters as specified in the contract. A non-contract smallholder avocado farmer on the other hand cultivates independently and sells to any available buyer.

2.1.1 Statement of the problem

Although there is a huge potential for avocado sector growth in Kenya, the increasing wave of traceability and standardization of the country's avocados to the largest importer, the EU, may thwart the realization and growth of this promising sector. In the study area, very few avocado farmers reported to be global gap certified, meaning that a substantial portion of smallholders without gap certification may be excluded from participating in the export value chain. The most viable option for majority of these smallholders to be co-opted in the food safety and quality value chain is through contract farming. Producing the fruit with the input or advice from the exporter will enable farmers to increase avocado yields while ensuring quality with ready market to sell the fruit, thus accruing maximum benefits from avocado production.

The general literature and various studies on Kenya have sought to investigate factors that influence smallholder participation in contract farming. However, previous studies, (see for instance Wainaina et al., 2012; Mwambi et al., 2013; Warning and Key, 2002; Birthal et al., 2008; Man and Nawi, 2010) did not investigate differences between contract and non-contract smallholder farmers in avocado production outcomes. Production outcomes such as quality and quantities of avocados produced and sold are indicators that show the productivity, efficiency and competitiveness of smallholder avocado production. These outcomes are also planning instruments that could be used to improve avocado production, project new markets and the overall sector's growth rate. Increase in avocado production and volume of sales while maintaining avocado quality, increases farmer's income and improves their welfare. The quality and quantities of avocados produced and sold are indicators that demand driven growth in avocado will create employment opportunities and increase the income of rural households. Investigating differences between the two groups in these production outcomes and identifying underlying factors for these differences therefore provide important additional information for policy intervention.

Against this backdrop, this essay contributes to existing literature on contract farming by firstly, analyzing factors influencing smallholder participation in avocado contract farming for which there is a dearth of information; secondly we use a framework that empirically analyze factors explaining differences in quality and quantities of avocado harvested and sold by contract and non-contract farmers taking into account selectivity bias that could result in overestimation of contract effect. To the best of our knowledge empirical evidence of such analysis in contract farming is scarce. Lastly, findings from this study have important policy implications on how smallholder avocado farmers could reap maximum benefits from production through contract farming given the current high local demand and export potential of the fruit.

2.1.2 Research questions

The study addresses the following questions:

i) What factors influence smallholder participation in avocado contract farming?

ii) To what extent do quality and quantities of avocados harvested and sold by contract and non-contract smallholder farmers differ?

iii) What policy options can be put in place to enhance smallholder participation in avocado contract farming?

2.1.3 Study objectives

The overall objective of this essay was to analyze smallholder avocado contract farming and to investigate the determinants and differentials in outcomes between contract and non-contract farmers. This is operationalized in the following specific objectives:

i) To investigate factors influencing smallholder participation in avocado contract farming.

ii) To assess the extent to which quality and quantities of avocados harvested sold by contract and non-contract smallholder farmers differ.

iii) To make policy recommendations for improved participation in contract farming.

The rest of the essay is organized as follows: Section 2.2 presents theoretical and empirical literature on contract farming. Section 2.3 presents methodology and data. Section 2.4 present results and discussion while section 2.5 presents summary, conclusion and policy implications.

2.2 Literature review on contact farming

2.2.1 Section overview

This section reviews theoretical and empirical literature on the determinants of smallholder participation in contract farming. Subsection 2.2.2 presents theoretical literature on contract farming; subsection 2.2.3 provides empirical literature review on participation in contract farming; while subsection 2.2.4 presents a summary of literature.

2.2.2 Theoretical literature on contract farming

The popularity of contract farming schemes in developing countries is attributed to the private sector oriented growth strategy of Structural Adjustment Programs (SAPs) in the 70's. Contract farming was an institutional framework which transformed rural agriculture by linking smallholders to export market through the private sector. The theoretical basis of contract farming is explained through Transaction Cost Theory from the New Institutional Economics (NIE) school of thought. Coase (1937) seminal presentation which laid out the framework for this school of thought posited that all business transactions involve costs which are mainly caused by uncertainty and asymmetric information. These two factors are interrelated and are mostly present in rural areas where market failure is pervasive. Hence contract farming serves as an effective mechanism in reducing overall cost of farm production, risk reduction and market uncertainty (Bijman, 2008). Since smallholder farmers in developing countries are faced with pervasive market failure, analysis of smallholder contract participation incentives requires models that incorporate both consumption and production decisions simultaneously as well as transaction cost due to market failure (De Janvry et al., 1991).

2.2.3 Empirical literature review

Contract farming has been criticized on grounds that it leads to social differences among farmers and causes increased concentration of land ownership, which leads to loss of independence for the growers (Echanove and Stefen 2005). There is however, a wider appeal in use of contract farming as a tool for integration of rural farmers in the value chain. Hence, there are a number of empirical studies advocating for the primary facet of contract farming: participation incentives, since contracts smallholders may differ in economic and social endowments.

Research by Warning and Key (2002) in Senegal to identify why smallholder farmers engaged in peanuts contract farming demonstrated that honesty played a significant role in smallholders' participation decision. Their analysis, which used probit model, also indicated that the value of agricultural assets influenced contract participation. In the same vein, Birthal et al., (2008) used a logistic regression model to analyze factors which encourage and/or hinder farmers' participation in dairy and vegetable contract farming in western state of Rajasthan, India. The authors found that endowments of land, educational attainment, experience, dairy stock, and access to nonfarm income sources influenced farmers' decision to participate in contract farming. Although Warning and Key, (2002) and Birthal et al., (2008) investigated farmers' participation incentive in contract farming, they did not however explore factors that may explain differences in production outcomes between contract and non-contract smallholders. This essay provides such analysis and factors that explains these differences.

Man and Nawi (2010) used factor analysis to identify why smallholder farmers engaged in fruits and vegetable contract farming in Peninsular Malaysia. The authors found that access to inputs and indirect market benefits, access to marketing information and technology transfer practices, were significant factors explaining contract participation. Using logit regression analysis, Wainaina et al., (2012) investigated factors that influenced smallholder participation in commercial poultry production in Nakuru County, Kenya. They found that male farmers dominated poultry contract farming and that farmer's risk attitude, distance from the main road, gender of the farmer, farm and non-farm income significantly explained contract farming decision.

Likewise, Mwambi et al., (2013) used probit regression analysis to investigate the determinants of smallholder participation in avocado contract farming in Kandara District, Kenya. The authors found that education, agricultural group membership, credit access, the quantity of productive *Fuerte* and *Hass* trees ownership, price of *Fuerte* and *Hass* significantly influenced contract participation. In Nepal, Kumar et al., (2016) used logistic regression analysis to investigate factors that prompted farmers' participation in lentil contract farming in a predominant smallholder context. Their results revealed that village location, household and firm sizes, mobile network connections and caste and were major determinants of farmers' participation in contract farming. Like previous authors, Man and Nawi (2010), Wainaina et al., (2012), Mwambi et al., (2013) and Kumar et al. (2016) did not analyze differences in production outcomes between contract and non-contract smallholder farmers on which this essay focuses.

In Indonesia however, Cahyadi and Waibel, (2013) investigated why smallholders participated in a contract scheme with a private oil palm corporation. The authors further explored differences in several performance indicators related to oil palm cultivation and production between contract participants and non-participants through descriptive analysis. The authors found that contract farmers were different from non-contract farmers in input per hectare usage, yield of plasma plot[2], received price, and share of oil palm to total net income. The probit analysis of participation indicated that migrant status, age of household head, size of plot and year the farm was established significantly explained farmer's participation decision in contract farming.

In the same vain, Tatlidil and Akturk (2004) used analysis of variance technique to analyze difference between tomato contract and non-contract growers in various indicators such as amount of seedlings used, value of fertilizer and chemical, irrigation, labor and machinery usage in Biga District of Canakkale Province Turkey. The results revealed a statistically significant difference between contract and non-contract farmers in the amount of seedlings, fertilizer and labor used in production. Although the studies by Cahyadi and Waibel, (2013); Tatlidil and Akturk (2004) provide useful insight into differences in production outcomes between contract and non-contract farmers, the use of simple statistics for analysis do not provide rigorious and causal information. Besides there are possible statistical estimation issues like selection bias and other individual characteristics that have to be controlled for.

This essay builds on Cahyadi and Waibel (2013), Tatlidil and Akturk (2004) by analyzing determinants of smallholder avocado contract farming and differentials in production outcomes between contract and non-contract farmers in Kenya.

2.2.4 Summary of literature review

Contract farming literature is mostly anchored on the theoretical framework of transaction cost posited by the New Institutional Economics theory. It is recognized as an institutional response to market failure. Given that smallholder farmers mainly face high transaction cost in accessing

[2] An oil palm plot cultivated by the smallholder with support measure from the oil palm company as specified in the contract.

market information and access to market, modelling the household economy requires a non-separable agriculture household model that incorporates transaction costs.

The above literature review indicates that the following factors influence participation in contract markets: farm/plot size (Kumar et al. 2016; Cahyadi and Waibel, 2013); education of farmer (Mwambi et al., 2013; Birthal et al. 2008); farmer's honesty and value of agricultural assets (Warning and Key, 2002); experience, endowments of land, dairy stock (Birthal et al., 2008); nonfarm income (Wainaina et al. 2012; Birthal et al. 2008); distance from market (Wainaina et al. 2012; Kumar et al., 2016; Guo et al. 2005); specialization and commercialization accompanied by government support (Guo et al. 2005); marketing information, market assurance, technology transfer, access to inputs (Man and Nawi, 2010); farmer's risk attitude, gender of farmer, farm income (Wainaina et al., 2012); credit access, agricultural group membership, number of productive *Fuerte* and *Hass* trees ownership, price of *F*uerte and *H*ass (Mwambi et al., 2013); household size, caste, and mobile phone connectivity (Kumar et al., 2016); migrant status, and age of household head (Cahyadi and Waibel, 2013).

The studies have mainly used - binary - probit or logit models to estimate contract participation decision. Although contract farmers may differ from their non-contract counterparts in some socio economic characteristics (Cahyadi and Waibel, 2013), the literature shows that there is a dearth of research in this area. Our study positions itself to address this research gap by investigating underlying factors that explain difference in quality and quantities of avocados harvested and sold by contract and non-contract farmers through a counterfactual decomposition analysis, while paying special attention to unobserved heterogeneities that may exist between the two groups.

2.3 Methodology

2.3.1 Section overview

This section presents the methodology used in this essay. Subsection 2.3.2 presents theoretical underpinnings, subsections 2.3.3 and 2.3.4 presents empirical models for factors influencing smallholder participation in avocado contract farming and the differences in production outcomes between smallholder contract and non-contract farmers respectively. Subsection 2.3.5 presents variable definition and measurement.

2.3.2 Theoretical underpinnings for participation in contract farming

The theoretical framework adopted for this essay is based on the non-separable agriculture model that incorporates transaction cost into the household utility maximization model (Singh et .al. 1986). The farmers' decision to participate in contract farming can be modelled as a utility maximization problem defined as:

$$U = U(C^m, C^a, l, Z^h) \qquad (2.1)$$

Where U is the utility, C^m, C^a, l and Z^h are market purchased goods, farm produced goods, leisure time and household characteristics. The household maximizes utility subject to time constraint T allocated between contract farming $L_{fc}(\tau)$, off-farm work L_{off} and leisure l

$$T = L_{fc}(\tau) + L_{off} + l \qquad (2.2)$$

The household faces a production function q that is concave and twice differentiable consisting of vector of inputs (X) that is conditional on contract participation (τ), farm labor dedicated to contract farming, contract participation and production technology characteristics (E).

$$q = q(X(\tau), L_{fc}(\tau), \tau, E) \quad \tau \geq 0 \qquad (2.3)$$

The utility function is subject to a budget constraint as specified by equation (2.4). Relaxing the assumption of perfect market, transaction cost is incorporated into the budget constraint through shadow prices.

$$p^s C + (t^c + p^m - p^s) C^m = p^s q - wX(\tau) + w^n L_{off} - (t^q - p^m + p^s) q^m + Y \qquad (2.4)$$

Where p^s and p^m are endogenous shadow price and market price respectively, $C = C^m + C^a$ represents total consumption of purchases, t^c and t^q denote transaction costs in purchase and sales of commodities respectively, $q = q^a + q^m$ denotes total crops produced for consumption and marketing, w and w^n are price of inputs and off-farm wage earned respectively, and Y denote other transfers received by households. Assuming an interior solution, the optimal conditions for contract participation are determined by the Kuhn-Tucker first order conditions (see derivation in Appendix 1).

2.3.3 Empirical model for smallholder participation in avocado contract farming

Avocado contract farming model can be derived from the first order condition from equation 2.4 defined in equation A1.7c (see Appendix1). Based on theoretical and empirical review of literature, the study hypothesizes that smallholder participation in contract farming is influenced by training in avocado agronomy. Other factors such as household characteristics (age, education level, gender of farmer and household size); agriculture as main occupation; physical and financial assets (such as number of *Hass* and *Fuerte* trees owned, value of assets, off-farm income and land ownership); social capital (includes frequency of attendance in avocado meetings and trust in other people); hired labor and transaction costs proxied by cost of marketing avocados, information on avocado production and marketing are also important covariates that influence contract farming (Coase, 1937; Mwambi et al., 2013). The contract participation model can thus be specified as:

$$P_i = F(H_i, A_i, T_i, S_i, : \beta) + \varepsilon_i \qquad (2.5)$$

where participation (P) is the dependent variable equal to one if the farmer participates and zero otherwise, i denotes a farmer, and a nonlinear function *F(.)*is a vector of covariates that include household characteristics (H), physical and financial assets (A), transaction costs (T) and social capital (S). β is a vector of parameters to be estimated and ε is the stochastic error term assumed to be normally distributed. Both logit and probit models are standard binary dependent variable models for estimating probability. The probit model however has the attraction of being motivated by a latent normal random variable that lies between $-\infty$ and βX_i such that the area under the curve represent the probability of participating in avocado contract farming (Cameroon and Trivedi, 2005). The functional form of the probit model based on the standard normal cumulative density function is specified as:

$$F(\beta X_i) = \int_{-\infty}^{\beta X_i} \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{z^2}{2}\right) dz \qquad (2.6)$$

Where z is a standardized normal variable and *exp* is the base of the natural log. The parameters of the probit model are estimated by maximum likelihood technique.

2.3.4 Decomposition framework

Decomposition analysis aimed at identifying and quantifying the influence of various factors to changes or differences in mean outcome is attributed to the pioneering work of Solow (1957). Solow's growth accounting approach quantified the contribution of labor, capital as well as the unexplained portion known as Solow's residual or total factor productivity to changes in economic growth in the United States. Since then, labor market and wage discrimination literature have extensively used the Oaxaca-Blinder (OB) decomposition model.

The threefold (OB) decomposition technique which emanated from the seminal work of Oaxaca (1973) and Blinder (1973) assumes a linear relationship and gives the mean difference in outcome. The mean difference further partitions the overall gap into endowment, coefficient and interaction effects. The endowment effect is a component of the overall gap that is due to differences in observable characteristics such as age, gender or productivity. The coefficient or unexplained portion is due to differences arising from returns to endowment and the interaction effect is due to the simultaneous change of endowment and coefficient effects. Although the OB decomposition technique is widely used in empirical studies to establish gaps in various phenomenon, the methodology has been criticized for not addressing the index number problem (the question of whether the gap is considered from the view point of contract or non-contract farmers) and also for not accounting for the possibility of selection bias.

Neumark, (1988), Oaxaca and Ransom, (1994) and Cotton, (1988) focused on the solution to the index number problem along separate lines. Neumark on one hand extended the Oaxaca methodology by deriving an alternative estimator of wage based discrimination which is based on the assumption that within each labor category, the underlying utility function is homogenous of degree zero with respect to labor inputs from each category. Appleton et al., (1999) however cautioned that although Neumark's decomposition has an advantage over Oaxaca's methodology in its solution to index number problem, it should be interpreted with some caution since it is not clear whether the pooled coefficients will in fact be a good estimator of the nondiscriminatory wage structure. Furthermore, there is no evidence that the zero-homogeneity restriction on employer preferences is valid. Jann (2008) also suggested that the decomposition technique proposed by Neumark may cause distortion of the decomposition estimates as a result of residual group difference spilling over into the slope parameters of the pooled model. Ways of addressing the selectivity problem as suggested by Neuman and Oaxaca (2004) is discussed later in this section.

Other decomposition of distributional parameters besides the mean such as quartile (Machado and Mata, 2005) and variance (Freeman 1984) have been proposed. However, analysis beyond the mean poses several econometric and methodological challenges. There are also other non-parametric method of decomposition that could be used such as one proposed by Machado and Mata (2005). This method however involves a number of assumptions and computational complexities. The limitations of other decomposition methods spelt above make the use of Oaxaca-Blinder (OB) technique more appealing for this study.

Recent studies by Fortin et al. (2010) and Sloczynsk (2012) have demonstrated that decomposition can be constructed within the framework of potential outcome model (Rubin, 1974). Following Fortin et al. (2010), we construct a counterfactual framework for a population of avocado farmers indexed by $i = 1,...,N$ distributed into two mutually exclusive groups denoted by a binary variable p_i where (P_i =1) if a farmer participates in contract farming (treatment group) and (P_i =0) for non-participation (control group) and an outcome variable Q_{ip} (quality and quantities of avocado harvested or sold). Thus for individual i, when (P_i =1) we observe Q_1 and when (P_i =0) we observe Q_{i0}. The observed potential outcome is specified as:

$$Q_{ip} = PQ_1 + (1 - P)\mathrm{Q}_0 \qquad (2.7)$$

The OB mean decomposition is based on a linear potential outcome model that allows regression coefficients to vary across the two groups.

$$Q_{ip} = X'\beta + \varepsilon_{ip} \quad \text{where} \quad \mathrm{E}[\varepsilon_{ip} \mid X_i, p_i] = 0 \quad p \in \{0,1\} \qquad (2.8)$$

From equation (2.8), the mean difference in quantity harvested or sold by contract and non-contract farmers can be separated into differences due to; i) $X's$ (observable characteristics), ii) β's (returns to endowment) and iii) ε (unobservable) depending on a simple counterfactual[3]. This type of counterfactual distribution helps us decompose differences in quality and quantities for both contract and non-contract farmers. The mean quality and quantities of avocado harvested and sold can be decomposed as follows:

$$
\begin{aligned}
E[Q_i \mid p_i = 1] - E[Q_i \mid p_i = 0] &= E[X_i \mid p_i = 1]\beta_1 - E[X_i \mid p_i = 0]\beta_1 \\
&= E[\mathrm{X}_i \mid p_i = 1]\beta_1 - E[\mathrm{X}_i \mid p_i = 0]\beta_1 + E[X_i \mid p_i = 0]\beta_1 - E[X_i \mid p_i = 0]\beta_0 \\
&= \underbrace{(E[X_i \mid p_i = 1] - E[X_i \mid p_i = 0])\beta_1}_{explained} + \underbrace{E[X_i \mid p_i = 0](\beta_1 - \beta_0)}_{unexplanned} \qquad (2.9)
\end{aligned}
$$

The explained component in (equation 2.9) is due to differences in endowment and the unexplained effect due to differences in returns to endowments. Sloczynsk (2012) has shown that the unexplained component of the OB decomposition can be expressed as the population average treatment effect of the treated (PATT) in treatment literature.

$$
\begin{aligned}
E[Q_i \mid p_i = 1] - E[Q_i \mid p_i = 0] &= (E[X_i \mid p_i = 1] - E[X_i \mid p_i = 0])\beta_1 + E[X_i \mid p_i = 0](\beta_1 - \beta_0) \\
&= E[Q_{i1} - Q_{i0} \mid p_i = 1] + \{E[Q_{i0} \mid p_i = 1] - E[Q_{i0} \mid p_i = 0]\} \\
&= \tau_{PATT} + \{E[Q_{i0} \mid p_i = 1] - E[Q_{i0} \mid p_i = 0]\} \qquad (2.10)
\end{aligned}
$$

Where τ_{PATT} (unexplained component) and "selection bias" represent the magnitude to which the control group (0) and the treated group (1) are on average different (explained component). According to Fortin et al., (2010) major assumptions necessary to support the understanding of OB result within the treatment framework include: i) Ignorability (conditional independence) indicated by $p_i \perp Q_{i0}, Q_{i1} \mid X_i$ which states that the returns to observables are the same for both groups after controlling for observable characteristics. ii) Overlapping support given by

[3] For the decomposition to follow partial equilibrium approach, we restrict our counterfactual to a simple counterfactual treatment in that the only alternative state of the world for contract farmers would be the return structure for non-contract farmers and vice- versa. This assumption rules out the existence of a third counterfactual for both groups.

$pr(p_i \mid X_i = x) < 1$ for all x ensures that nothing in the error terms or observed factors is attributed to selection into any of the groups being compared.

2.3.5 Empirical model for differences in avocados quality, quantities harvested and sold by contract and non-contract farmers

Following the decomposition framework above, the Oaxaca-Blinder decomposition framework is used to estimate differences in production outcomes between contract and non-contract farmers. The production of high yield and quality avocado requires good crop management of fruit disease that destroys avocado quality, soil enrichment and production practice. Based on empirical literature review, the essay hypothesizes that, farmers' agronomy knowledge in fertilizer and pesticide application, frequency of pruning, record keeping on input used in production explain differences in production outcomes between contract and non-contract farmers (Cahyadi and Waibel, 2013; Tatlidil and Akturk, 2004).

The quantities of avocados sold and harvested are linear in parameters and thus can be modelled using the linear regression model. The quality of avocados sold is a binary variable and as such the linear probability model (LPM) is used. The LPM is one of the most popular models used in the social sciences to model binary outcomes. Several authors have pointed to interpretation and computational simplicity of the LPM compared to non-linear models (Betts and Fairlie, 2001). Wooldridge (2010) advised the use of LPM when the goal is estimation of inference. Maddala, (1983) however criticized the model on grounds that the disturbance of the LPM are heteroscedastic therefore OLS is not efficient. Moreover, the predicted values which reflect probabilities are not constrained to the unit interval and also the normality of the error term is not valid, therefore, non-linear procedure which is more efficient than least squares should be used.

Angrist and Pischke, (2008) indicated that with a larger sample size the sample moments would be approximately normally distributed. The authors further iterated that because the underlying data generation is typically unknown, the choice of model whether logistic, probit, or LPM can only be assumed as an approximation. Friedman et al., (2009) also stated that these violations themselves do not guarantee that the LPM approach will not work, and in fact on many occassions it gives similar results to more standard linear methods for classification. The criticism against the LPM is so far debatable.

The regression equation modelling the relationship between quantities of avocados harvested and sold by farmer i (Q_i) and explanatory variables for both contract and non-contract farmers follows from the standard OB decomposition of wage differences equation which is specified as:

$$\ln Q_i = \begin{cases} \beta_1 x_i + \varepsilon_1 \text{ if } c \\ \beta_0 x_0 + \varepsilon_0 \text{ if } nc \end{cases} \quad (2.11)$$

Where $\varepsilon's$ are error terms assumed to be normally distributed while c and nc denote contract and non-contract. From equation (2.11) the difference or gap in quality and quantity of avocado produced and sold ($Q_c - Q_{nc}$) for contract smallholders Q_c and non-contract can be decomposed into three parts as follows:

$$\overline{Q}_c - \overline{Q}_{nc} = (\overline{X}_c - \overline{X}_{nc})\beta_{nc} + \overline{X}_{nc}(\beta_c - \beta_{nc}) + (\overline{X}_c - \overline{X}_{nc})(\beta_c - \beta_{nc}) \quad (2.12)$$

$$= \mathrm{A}_0 + A_1 + A_2$$

The standard OB decomposition is explained from the viewpoint of the disadvantaged group, in this case, non-contract farmers. Following Jann (2008), this difference can be thought of as being due in part (A_0) to difference in endowment between contract and non-contract farmers weighted by the coefficient of non-contract farmers. (A_0) seeks to explain by how much the mean quality and quantities of avocados produced and sold by non-contract farmers will increase or decrease if they were given the endowments of contract farmers. (A_1) measures the coefficient or returns effect weighted by the endowment of non-contract farmers and measures the outcome of non-contract farmers if their endowments were rewarded as contract farmers and (A_2) is the interaction effect which measures the simultaneous effect of both difference in endowment and returns to endowment. The mean gap between contract and non-contract farmers can be denoted as:

$$Gap = E(Q_c) - E(Q_{nc}) = E(\mathrm{Q}_c)'\beta_c - E(Q_{nc})'\beta_{nc} \quad (2.13)$$

Where β 's are estimates of the group specific regression of equation (2.11). We assume that $E(\varepsilon_c) = 0$ and $E(\varepsilon_{nc}) = 0$.

The standard OB decomposition can be estimated using ordinary least squares (OLS) estimation technique. The decomposition framework in equation (2.10) however suggest plausible econometric issues such as selectivity bias that leads to biased and inconsistent OLS estimates. For instance, there may be some unobservable factors that influence farmer's self-selection into contract farming that may also be correlated with the quality and quantities of avocados harvested and sold. This selection bias can be controlled for using the inverse Mills ratio IMR, (Wooldridge, 2002). The ratio is calculated from the probit model and added as an explanatory variable to the quality and quantity equations for both contract and non-contract farmers. Thus we assume that in addition to the out-put model equation (2.11), there is an additional model that determines participation in contract farming given by:

$$Y_i^* = Z_i^{'}\delta + \upsilon_i \qquad (2.14)$$

Where Y_i^* is a latent variable related to participation in contract farming, Z is a vector of covariates related with the associated parameter vector δ and υ_i is an error term that is normally distributed $(0, \sigma_v)$. Normalizing the variance υ_i =1, the correlation between υ_i and ε_i in the quantity equation is measured by γ. Thus the probability of participation in contract farming is given by:

$$\Pr(\mathrm{Y}_i^* > 0) = Pr(v_i > Z_i^{'}\delta) = \Phi(Z_i^{'}\delta) \qquad (2.15)$$

Where $\Phi(.)$ is the standard normal cumulative distribution function (CDF). Combining the participation and output equation gives the expected quality and quantities of avocados harvested and sold by a farmer observed to participate in contract as:

$$\mathrm{E}(\mathrm{Q}_i \mid Y_i^* > 0) = X_i^{'}\beta + E(\varepsilon_i \mid v_i > Z_i^{'}\delta) = X_i^{'}\beta + \theta\lambda_i \qquad (2.16)$$

Where $\theta = \rho\sigma_v$ is the covariance between the two error terms, $\lambda = \phi(Z_i^{'}\delta) / \Phi(Z_i^{'}\delta)$ is the inverse Mills ratio and ϕ is the standard probability density function. The quantity and quality model can now be specified as follows:

$$: \ln Q_i = X_i^{'}\beta_i + \theta\lambda_i + \varsigma_i \qquad (2.17)$$

ς_i is the zero mean residual. The inclusion of the inverse Mills ratio in equation (2.17) corrects for selectivity bias and gives a consistent estimate of β. However for the purpose of identification, a variable which is expected to influence participation but less likely to affect quality and quantities of avocados harvested and sold is excluded from the outcome equation. A statistically significant coefficient of the inverse Mills ratio implies selection bias, while an insignificant coefficient is an indication that selectivity does not result in significant bias. Hence, equation (2.11) can be estimated using OLS without the Mills ratio. Neuman and Oaxaca (2004) have shown that with adjustment in the quality and quantity equation, the decomposition equation can also be amended to incorporate the selectivity term. This is specified as follows:

$$\bar{Q}_n - \bar{Q}_{nc} = \underbrace{\bar{X}'_{nc}(\hat{\beta}_c - \hat{\beta}_{nc})}_{Coefficient} + \underbrace{(\bar{X}_c - \bar{X}_{nc})\hat{\beta}_{nc}}_{Endowment} + \underbrace{(\hat{\theta}_c \hat{\lambda}_c - \hat{\theta}_{nc} \hat{\lambda}_{nc})}_{Selectivity} \qquad (2.18)$$

Where $\hat{\theta}$ is the estimate of $\rho\sigma_\varepsilon$, and $\hat{\lambda}$ estimate of the mean IMR. The selectivity term captures the selection effects contributed to the observed gap in quality and quantities of avocados harvested and sold.

Definition of variables

The dependent variable is the participation decision which equals one if a household participated in avocado contract farming and zero otherwise. For difference in participation between smallholder contract and non-contract farming, the dependent variables are the mean difference in quality and quantities of avocados harvested and sold. Avocados are sold per piece according to traditional parameters such as size, shape of the variety and quality. Quality considerations include color, external skin defects and maturity. Mature fruits are firm and have an oil content of at least 15 percent. Based on these characteristics, avocados are placed into high, medium/normal and low grade quality. Healthy, mature and good looking fruits are classified as high quality while those with slight difference in shape or size but mature are placed in the medium/normal category. Injured, diseased, discolored or immature fruits are placed in the low grade category.

Exporters mostly prefer the high and medium quality grade. The high or normal grade quality fetches a higher price than the low grade. Farmers were asked about the quantities of avocados harvested, quality and quantities sold. Avocado quality was initially coded as a categorical variable with 1 indicating high quality, 2 medium/normal quality and 3 low quality. Since both high and medium/normal are usually purchased by exporters or supermarkets, the variable was recoded as dummy variable. High and medium qualities were collapsed into one category and given the value one to represent good quality avocados sold and zero as low quality. Quantities of avocados harvested and sold are continuous variables measured as the total pieces of avocados harvested and sold by farmers.

Independent variables

Based on review of literature, independent variables that influence smallholder participation in contract farming as well as differences between contract and non-contract farmers are grouped as indicated in (Table 2.1). These are: i) household characteristics; ii) physical and financial assets; iii) Transaction costs and social capital and iv) agronomy knowledge (Cahyadi and Waibel, 2013; Tatlidil and Akturk, 2004).

Table 2.1: Definitions, Measurement of Independent Variable and Expected Signs

Variables		Expected impact		Literature source
		Participation	Difference in participation	
H	**Household characteristics**			
	Age of farmer (years)	Positive	Positive	Simmons et al.,(2005); Cahyadi and Waibel (2013); Kumar et al., (2016)
	Household size (no. of persons)	Positive	Positive	Birthal et al., (2008)
	Gender dummy (male=1)	Positive	Positive	Wainaina et al., (2012
	Education level (years)	Positive	Positive	Birthal et al., (2008); Simmons et al., (2005); Wainaina et al., (2012) Mwambi et al., (2013)
	Main occupation of household head (farming=1)	Positive	Positive	Wainaina et al., (2012)
A	**Physical and financial asset**			
	Value of assets (Ksh)	Positive	Positive	Warning and Key (2002)
	Land size (acre)	Positive	Positive	Simmons et al.,(2005); Cahyadi and Waibel (2013); Kumar et al. (2016); Birthal et al.,(2005)
	None farm income (Ksh)	Positive	Positive	Birthal et al., (2008); Simmons et al., (2005); Wainaina et al., (2012)
	Number of productive *Hass* and *Fuerte* avocado trees owned	Positive		Mwambi et al., (2013)
T	**Transaction cost and social-capital**			
	Monetary costs of marketing avocados (Ksh)	Negative	Positive	Guo et al., (2005)
	Received production & market information (yes=1)	Positive	Positive	Man and Nawi (2010)
	Hired labor (yes=1)	Positive	Positive	Begum et al., (2013)
	Household member received training in avocado production year (yes=1)	Positive	Positive	Begum et al., (2013)
	Trust in other people (index)	Positive	Positive	Wainaina et al., (2012)
	Number of avocado group meetings participated in the last 12 months	Positive	Positive	Mwambi et al., (2013)

K	**Agronomy Knowledge**			
	Fertilizer and pesticide application rate (kg/tree)		Positive	Tatlidil and Akturk (2004); Cahyadi and Waibel (2013)
	Grafting of trees (yes=1)		Positive	Tatlidil and Akturk (2004)
	Pruning of trees (at least once a year =1: 0 otherwise)		Positive	Tatlidil and Akturk (2004)
	Record keeping on inputs used & production (yes=1)		Positive	Tatlidil and Akturk (2004)

2.3.6 Data and descriptive statistics

This essay used household data collected by the Productive Employment in Segment Markets of Fresh Produce (PRESM) project collected between November-December 2015 in Murang'a County, Kenya. Tables 2.2-2.5 present descriptive statistics of variables used in the analysis. The descriptive statistics gives comparison of the mean values of selected variables for a sample of 790 farmers. Among the three groups of farmers sampled, 266 had existing contracts with local firms and exporters, 144 known as transition farmers were newly organized into groups to sign contracts with SME's and 380 farmers were without contracts.

Transition and non-contract farmers were classified as non-contract farmers and those with established contracts as contract farmers. This grouping was necessitated by preliminary analysis which indicated that transition and non-contract farmers had more commonalities in various characteristics than contract farmers; and although transition farmers had formed groups, most of them had not yet signed any contract agreements. Table 2.2 presents mean comparison test results of quality and quantities of avocados sold by contract and non-contract farmers. Results show that the two groups were significantly different in the three avocado production indicators. .Approximately 8,780 avocados were harvested by farmers while 7,777 pieces were sold. Contract farmers however harvested and sold 10,832 and 9,820 pieces respectively while their non-contract counterparts harvested and sold 7,738 and 6,739 pieces respectively. About 63 percent of contract farmers rated their avocados as high or normal quality while this was true for 43 percent of non-contract farmers.

Table 2.2: Mean Comparison Tests Results of Quality and Quantities of Avocados Harvested and Sold

	Non-contract N=524		Contract N= 266		All farmers N=790		
Variables	Mean	SD	Mean	SD	Mean	SD	T- stat
Quantity harvested	7,738.48	11835.39	10,832.85	12327.26	8,780.36	12105.08	-3.74***
Quantity sold	6,739.09	8878.05	9,820.35	1183.31	7,777.91	1011.53	-4.75***
Avocado quality	0.43	0.49	0.63	0.48	0.49	0.50	-5.35***

*significant at 1%

Household characteristics

The characteristics of smallholder contract and non-contract avocado farmers in the sampled area are presented in Table 2.2. The mean age of all avocado farmers was about 61 years, that of contract farmers was 62.4 years while that of non-contract farmers was 60.6 years. The difference in age was significant at 10% level. The mean age of farmers shows that avocado is mostly produced by elder farmers. On average, households comprised of about four persons, with male heads constituting about 79 percent. Farmers attained on average 8 years of education and 87 percent of them had farming as their major occupation. There was no significant difference across the two sub samples in educational attainment and occupation.

Table 2.3: Mean Comparison Tests Results of Household Characteristics

	Non-contract N=524		Contract N= 266		All farmers N=790		
variables	Mean	SD	Mean	SD	Mean	SD	T- stat
Age of farmer (years)	60.55	13.95	62.44	13.39	61.19	13.78	-1.82*
Gender dummy (Male=1)	0.77	0.42	0.82	0.38	0.79	0.41	-1.61
Household size (no of persons)	3.59	1.84	3.67	1.77	3.62	1.82	-0.57
Education of household head (years)	7.85	3.94	8.22	3.50	7.97	3.80	-1.30
Main occupation of household head (farming=1; 0 otherwise)	0.87	0.34	0.88	0.33	0.87	0.33	-0.46

*significant at 10%

Physical and financial assets

Mean test results from Table 2.3 shows that the value of asset and off-farm income was about 39,944.9 and 109,581.7 Kenyan shillings respectively. Avocado farmers owned about 2 acres of land, 9 *Hass* and 5 *Fuerte* trees. A clear distinction was observed in the physical and financial endowment of assets between contract and non-contract farmers. The total asset value of contract farmers was at least twice as high as non-contract farmers. We however uncovered no significant difference in the amount of non-farm income received by the two groups. Contract farmers owned 21 percent more acres than non-contract farmers and thrice as much productive *Hass* trees than non-contract farmers. The t-test showed a weakly significant difference between contract and non-contract farmers in the number of *Fuerte* trees owned.

Table 2.4: Mean Comparison Tests Results of Physical and Financial Assets

Variable	Non-contract N=524		Contract N= 266		All farmers N=790		
	Mean	SD	Mean	SD	Mean	SD	T-stat
Value of assets (Ksh)	29,431.7	73105.0	60,655.3	165330.0	39,944.9	113759.5	-3.67***
Non-farm income(Ksh)	108,513.6	240115.3	111,685.8	158,795.8	109,581.7	216,076.9	-0.19
Total land owned (acre)	1.96	1.82	2.37	2.11	2.10	1.93	-2.86***
Number of productive *Hass* tress	5.61	12.13	14.49	19.66	8.60	15.65	-7.82***
Number of productive *Fuerte* trees	4.71	9.07	5.83	8.46	5.09	8.88	-1.69*

*, *** Significant at 10% and 1%

Transaction cost and social capital

Table 2.4 presents t-test results for differences in transaction costs and social capital for contract and non-contract farmers. The result shows that on average more contract farmers received information on avocado production and marketing and had more household members trained in avocado agronomy than their non-contract counterparts. Farmers on average spent 65 cents per piece to market their avocados but contract farmers spent 8 times more than their non-contract counterparts. They hired about 66 percent of labor for production while non-contract participants hired only 43 percent of labor. Contract farmers were more frequent at avocado group meetings than non-contract participants. Questions of farmer's trust in other people were aggregated as an index. The reasoning behind a possible association of trust and contract farming is that people, who in general trust that others will look after their interests, have fewer concerns about the risk and uncertainty of entering contract agreements. The results however revealed no significant difference between the two groups in trust and perception of other people.

Table 2.5: Mean Comparison Tests Results of Transaction cost and social capital

	Non-contract N=524		Contract N=26		All Farmers N=790		
variables	Mean	SD	Mean	SD	Mean	SD	T-stat
Transaction cost							
Received information on prod. & marketing (yes=1)	0.20	0.40	0.35	0.48	0.25	0.43	-4.48***
Household member rec. training in avocado prod. year (yes=1)	0.23	0.42	0.74	0.44	0.40	0.49	-15.98***
Cost of marketing avocados (Ksh/piece)	0.02	0.08	0.16	17.98	0.65	12.09	-9.98***
Hired labor (yes=1)	0.43	0.50	0.66	0.47	0.51	0.50	-6.14***
Social capital							
Frequency of avocado meeting attendance (no. in a year)	8.06	4.12	12.85	12.15	10.01	7.96	-4.71***
Trust in other people (index)	0.57	0.13	0.58	0.13	0.58	0.13	

***Significant at 1%

Agronomic knowledge

The mean test results indicated that more contract farmers received training in avocado agronomy than non-contract farmers. On average avocado farmers applied approximately 4.7 kilograms of manure and fertilizer, 79 percent of farmers did grafting, 61 percent pruned their trees at least once a year while only 10 percent kept records on inputs used and production. There were however some significant difference between contract and non-contract farmers in their knowledge and application of avocado agronomy. Contract farmers applied on average 5.75 kg of fertilizer and pesticide, while only 4.16 kg was applied by non-contract farmers. Eighty eight percent of contract farmers grafted their avocado trees while this was true for only 75 percent of non-contract farmers. The two groups also differed in the frequency of tree pruning and record keeping on inputs used and production.

Table 2.6: Mean Comparison Tests Results of Avocado Farmers' Agronomic Knowledge

	Non-contract N=524		Contract N= 266		All farmers N=790		
variables	Mean	SD	Mean	SD	Mean	SD	T-stat
Household member received. training in avocado production year (yes=1)	0.20	0.40	0.35	0.48	0.25	0.43	-4.48***
Fertilizer & pesticide application rate (kg/tree)	4.16	2.54	5.72	1.92	4.68	2.46	-8.787***
Grafting of trees (yes=1)	0.74	0.44	0.88	0.33	0.79	0.41	-4.52***
Pruning at least once a year (yes=1)	0.56	0.50	0.70	0.46	0.61	0.49	-3.737***
Record keeping on input used & prod (yes=1)	0.07	0.25	0.16	0.37	0.10	0.30	-4.007***

***Significant at 1%

2.4 Empirical results and discussion

2.4.1 Section overview

This section presents findings and discussion of results. Subsections 2.4.2 presents regression results for avocado contract farming adoption and subsection 2.4.3 presents decomposition results of differences in production outcomes between contract participants and non-participants respectively.

2.4.2 Regression results for avocado contract participation

This sub-section presents analysis of factors that influenced smallholder participation in avocado contract farming. The essay used the binary probit model, whose coefficients and marginal effects are presented in Table 2.7. Preliminary diagnostic test for multicollinearity showed that there was no collinearity amongst variables. For the robustness of our result, robust standard errors were used to control for potential heteroscedasticity. The probit model correctly predicted 87% of the observed outcome with most variables showing high significance. Wald Chi sq. value of 126.55, significant at 1 percent level indicated that our model fitted the data well. The Pearson or Hosmer–Lemeshow‘s goodness of fit test returned a probability greater than Chi^2 of 0.8757. Classification test of model sensitivity and specificity with a cut-off of 0.5 percent also showed a high model fit.

The average marginal effects from the probit model in Table 2.7 indicates that the age of the household head, used as a proxy for experience in avocado production was positive and significant, showing that as farmers grew older and gained more experience in avocado farming, they become more confident to participate in contract farming. This result supports findings by Bellemare and Novak (2016) who indicated that farmer's age was important determinant of contract participation for ten contracted crops across six regions of Madagascar. Wainaina et al., (2012) on the other hand found no significant relationship between farmer's age and poultry contract farming.

Mugwe et al., (2009) argued that using age as a crude proxy for experience may have a cohort effect as changes in technology, information and risk attitude may affect the probability of contract adoption of farmers in different age brackets. As such, findings of the effect of age may not be conclusive. Household assets had significant and positive effect on the probability of contract participation. Assets aid smallholders in production and hence increase their chances of participating in contract farming. This finding corroborates the study of Warning and Key (2002) who found a significant and positive effect of assets on peanut contract farming in Senegal. Mwambi et al., (2013) however found no significant relationship for poultry farming in Kenya.

The results further indicated that the number of mature *Hass* trees owned significantly influenced contract farming. Specifically, the result showed that an increase in the number of productive *Hass* trees increased the chance of participating in contract farming by 0.5 percentage points. This result can be explained by the fact that *Hass* is the most preferred avocado variety for export. Reason being that *Hass* is less prone to pests and disease attacks and has a longer shelf-life compared to *Fuerte.* As such, farmers with more *Hass* trees belong to a contract scheme as this increases their chances of participating in the export market. The result for the number of *Fuerte* trees was positive, but insignificant. This is probably due to the low export demand for *Fuerte* avocados which may not provide adequate incentives for farmers to participate in contract farming.

Analysis further showed that hiring labor for avocado production and marketing was positively correlated with avocado contract farming, suggesting that as more farmers join contracts, there is a higher likelihood of hiring more workers. This is an indication that the sector could generate employment by using family labor as well as hired labor. Monetary cost of transporting avocados to market was a strong predictor of contract participation. A one percent increase in the cost of marketing avocados increased the probability of participating in contract farming by 63 percentage points. The perishability of avocados coupled with the cost of transporting the fruit probably explains why most non-contract farmers sell their avocados at the farm gate at relatively lower prices. Hence, farmers who live in remote areas may find additional security in contract farming (Wang et al., 2014). Participation could help them enjoy economies of scale rather than transporting produce individually to the market or relying entirely on brokers. This finding is in line with Leung et al., (2008) findings on rice contract farming in Lao PDR. Wainaina et al., (2012) however found that the distance to market reduced the likelihood of contract participation for poultry farmers.

The frequency of meeting attendance in avocado group meetings significantly influenced contract participation. Group membership plays an important role in contract farming. Most buyers prefer contracting with group since monitoring of individuals within the group can be carried out by group leaders which is more cost effective for them. Although being a group member is a necessary step to contract participation, active participation in the group through meeting attendance leads to more social interactions and group commitment to participate and upholding contract agreements. This finding is consistent with literature on group association (Wainaina et al., (2012). A member of the household receiving trainings in avocado agronomy and post-harvest management was positively related to contract farming. This means that strengthening farmer's capabilities through training helps them produce quality and healthier avocados and the opportunity to join the avocado value chain through participation in contracts.

As expected, the result showed that the acquisition of production and marketing information increased the likelihood of smallholder participation in contract farming by 1.1 percentage point. This suggests that acquisition of specialized information concerning fertilizer and pesticide application, timing of harvest, management of product quality and other technical information are vital for enhancing avocado quality and better prices for farmers. Man and Nawi (2010) made similar conclusion on access to information on production and marketing of vegetable contract farming in Malaysia.

Table 2.7: Probit Regression of Factors influencing Participation in Avocado Contract Farming

	Maximum Likelihood Estimates			Average Marginal Effects	
Variables	Coef.	SE	P-value	Coef.	SE
Household characteristics					
Age of household head (years)	0.010	0.005	0.026	0.002**	0.001
Gender dummy (Male=1)	-0.112	0.134	0.403	-0.027	0.032
Household size (no. of	0.043	0.034	0.200	0.011	0.008
Education of household head (years	-0.001	0.017	0.962	0.000	0.004
Main occupation of household (Farming=1)	-0.146	0.177	0.409	-0.035	0.043
Physical and financial assets					
No of productive *Hass* trees	0.022	0.006	0.000	0.005***	0.001
No of productive *Fuerte* trees	-0.002	0.007	0.817	0.000	0.002
Land owned (acre)	0.011	0.030	0.720	0.003	0.007
ln total assets (Ksh)	0.028	0.056	0.621	0.007**	0.014
Non-farm income (Ksh)	-0.005	0.019	0.812	-0.001	0.005
Credit constrained (yes=1)	0.003	0.153	0.984	0.001	0.037
Hired labor (yes=1)	0.003	0.001	0.000	0.001***	0.000
Cost of transporting avocado to market (Ksh)	2.609	0.896	0.004	0.631***	0.211
Training, information and social capital					
Trust in other people (index)	0.176	0.402	0.661	0.043	0.097
Frequency of avocado meeting attendance (no. in a year)	0.015	0.007	0.030	0.004**	0.002
Received information on avocado production & marketing (yes=1)	0.044	0.158	0.050	0.011**	0.038
House member received training on avocado production (yes=1)	1.118	0.136	0.000	0.270***	0.030
Constant	-2.458	0.716	0.001		
Number of observations				777	
Wald chi2(18)				237.45	
Prob > chi2				0.0000	
Pseudo R^2				0.3270	
Pearson or Hosmer–Lemeshow 's test (Prob > chi2)				0.8647	
Correct classification				82.03%	

*, **, *** Significant at 10%, 5% and 1%

2.4.3 Results of Oaxaca-Blinder decomposition

The Oaxaca-Blinder decomposition was used to uncover the gap and its sources between contract and independent farmers in quality and quantities of avocados harvested and sold. In addition to household characteristics, physical and financial assets as well as other socio-economic variables used in the probit analysis, farmer's agronomic knowledge such as pruning and grafting of avocados, fertilizer and pesticide application rate and record keeping were controlled for. This was done for both the contract and non-contract farmers. For the decomposition analysis, non-contract farmers were defined as the counterfactual group of interest from whose perspective the results were reported. The OB decomposition is based on regression analysis that proceeds in two stages. In the first stage, group specific regressions models were estimated for the production outcome variables quality and quantities of avocados harvested and sold. In the second stage, mean values and estimated parameters from the first stage regression were used for decomposition.

For robustness check, two different equations were estimated for each outcome. The OB equation that accounted for selection and another that did not account for selection. In the first estimation, the inverse Mills ratio was estimated from the probit model of participation and included in the OB decomposition as an additional variable in the outcome equations to control for selection bias. The coefficients of the inverse Mills ratio were however insignificant in the quality and quantities of avocados sold estimates. In the quantities harvested equation, the inverse Mills ratio equations showed a marginal significance for only the endowment component of the individual variable contribution whiles the coefficient and interaction effects were insignificant. Even with the marginal significance in the endowment variable, the signs of the coefficients were not intuitive. We therefore proceeded to use the OLS estimator for the OB decomposition. For estimation results accounting for selection bias, (see Appendix Table A1).

Table 2.8 presents results from the first stage OLS estimation that characterized the gaps in quality and quantities of avocados harvested and sold. The three models for both contract and non-contract farmers were significant at 5% with robust standard error estimated for robustness of results. With respect to quantities of avocados harvested, Table 2.8 shows that household size, education of the household head, the number of productive *Hass* and *Fuerte* trees owned land size, non-labor income, fertilizer and pesticide application rate, frequency of avocado meeting attendance, information on production and marketing and grafting of avocado tree were significant predictors of quantities of avocados harvested. However, information on production and marketing, frequency of avocado group meeting grafting of avocado tree, non-farm income and hired labor were significant only for contract farmer; although non-farm income and hired labor showed marginal significance. On the other hand, the coefficient of land was positively significant for non-contract farmers but showed no statistical significance for contract farmers. This suggests the possibility of non-contract farmers allocating more land to avocado production which could increase their quantities harvested. The insignificant effect of land on avocado quantities harvested for contract farmers could be that they may have already allocated their lands to avocado production.

In quantities sold, education of household head, the number of productive *Hass* and *Fuerte* trees owned, hired labor, cost of marketing avocados, receiving information on avocado production and marketing, grafting and pruning of avocado trees as well as fertilizer and pesticide application rate were positive and significant determinants. Notable, for non-contract farmers, a one percent increase in transport cost, reduced quantities of avocados sold by 2.5 percent. This result supports earlier findings in Table 2.7 which revealed that cost of marketing avocados was a vital determinant of contract participation. On the other hand, education, hired labor and grating of avocado trees were significant only for contract farmers.

Results for the quality of avocados sold indicated that the age, gender and education of the farmer, number of productive *Hass* trees owned, hired labor and fertilizer and pesticide application rate were significant predictors. Specifically, the result highlights an inverse relationship between age and quality of avocados produced and sold by contract farmers. And that being a male contract farmer increased quality of avocados sold. Training was also highlighted as an integral part of avocado quality. An additional household member of a contract farming household trained in avocado agronomy increased the quality of avocados produced and sold by 15 percent. On the overall, household endowment in *Hass* and *Fuerte* trees, training in avocado agronomy and their application and hired labor played a major role in quantities of avocados harvested and sold while the demographic characteristics of the farmer along with training were also important for avocado quality.

Table 2.8: OLS Estimates of Avocado Quality, Quantities Harvested and Sold

	Quantities Harvested		Quantities Sold		Quality Sold	
Variables	Non-contract	Contract	Non-contract	Contract	Non-contract	Contract
Age of household head	0.001	0.003	0.001	-0.002	0.007	-0.009***
(years)	(0.004)	(0.005)	(0.006)	(0.006)	(0.002)	(0.003)
Gender dummy (Male=1)	-0.014	0.079	0.012	0.102	0.020	0.141*
	(0.112)	(0.143)	(0.173)	(0.193)	(0.057)	(0.084)
Household size (no. of	0.014	0.003	0.007	-0.027	0.010	-0.004
Persons)	(0.026)	(0.033)	(0.040)	(0.045)	(0.013)	(0.019)
Education of household head (years)	0.023*	0.043***	0.004	0.063***	0.012*	0.020**
	(0.013)	(0.017)	(0.020)	(0.023)	(0.007)	(0.010)
Main occupation of household (farming=1)	-0.179	-0.047	-0.243	0.015	0.113	-0.094
	(0.136)	(0.172)	(0.211)	(0.231)	(0.069)	(0.100)
No of productive *Hass* trees	0.028***	0.016***	0.026***	0.019***	0.002	0.001**
	(0.004)	(0.003)	(0.007)	(0.004)	(0.002)	(0.002)
No of productive *Fuerte* trees	0.031***	0.051***	0.036***	0.059***	0.000	0.061
	(0.005)	(0.006)	(0.008)	(0.009)	(0.003)	(0.004)
Land owned (acre)	0.092***	0.031	0.069*	0.032	0.026*	0.039
	(0.026)	(0.029)	(0.041)	(0.039)	(0.014)	(0.017)
ln total assets (Ksh)	-0.009	0.035	0.009	0.019	0.007	0.002
	(0.041)	(0.037)	(0.063)	(0.050)	(0.021)	(0.002)
Non-farm income (Ksh)	0.008	0.032*	0.002	-0.033	-0.006	-0.005
	(0.015)	(0.018)	(0.024)	(0.024)	(0.008)	(0.011)
Credit constrained (yes=1)	-0.076	-0.105	-0.140	-0.026	0.057	0.052
	(0.118)	(0.150)	(0.183)	(0.202)	(0.060)	(0.087)
Hired labor (yes=1)	0.001	0.005*	0.001	0.001**	0.008	0.008*
	(0.001)	(0.003)	(0.001)	(0.010)	(0.011)	(0.001)
Cost of transporting avocado to market (Ksh)	-1.470	-0.074	-2.458***	-0.103	0.120	0.025
	(0.566)	(0.063)	(0.878)	(0.085)	(0.283)	(0.037)
Group meeting attendance (no. in a year)	0.043	0.055**	-0.019	0.006	-0.008	0.001
	(0.011)	(0.004)	(0.017)	(0.006)	(0.005)	(0.003)
Trusting people (index)	0,316	0.398	0.227	0.427	-0.252	-0.228
	(0.335)	(0.394)	(0.519)	(0.530)	(0.168)	(0.229)
Rec. information on avocado production and marketing (yes=1)	0.127	0.673***	0.347**	1.195***	0.009	0.184
	(0.101)	(0.207)	(0.157)	(0.279)	(0.052)	(0.124)
House member received	0.064	-0.017	-0.019	-0.062	0.082	0.152***

training in avocado production (yes=1)						
	(0.118)	(0.157)	(0.182)	(0.211)	(0.059)	(0.091)
Pruning at least once a year (yes=1)	0.092	0.060	0.319**	0.036**	0.044	0.072
	(0.092)	(0.108)	(0.143)	(0.145)	(0.047)	(0.063)
Grafted avocado tree (yes=1)	0.358	0.127***	0.044	0.533***	-0.046	0.100
	(0.105)	(0.163)	(0.162)	(0.219)	(0.053)	(0.095)
Fertilizer & pesticide Application rate(kg/tree)	0.001**	0.023***	0.005*	0.003**	0.011**	0.032***
	(0.002)	(0.101)	(0.002)	(0.001)	(0.003)	(0.122)
Keeping records of input use & Production (yes=1)	0.031	-0.054	0.207	-0.105	0.166*	0.087
	(0.178)	(0.142)	(0.276)	(0.191)	(0.091)	(0.082)
Constant	7.667***	7.038***	6.898***	6.594***	0.154***	1.055***
	(0.510)	(0.562)	(0.790)	(0.757)	(0.260)	(0.329)
N	523	263	523	263	523	263
R-squared	0.309	0.370	0.279	0.377	0.359	0.339

Robust standard error in parenthesis *, **, *** Significant at 10%, 5% and 1%

OLS Oaxaca-Blinder aggregate decomposition of quantities of avocados harvested, quality and quantities sold

The OB decomposition results presented in Table 2.9 gives the mean predictions for contract and non-contract farmers, gap and its components (the endowment, coefficient and interaction effects) for quantities of avocados harvested, quality and quantities sold. The mean predictions and gaps for the three outcome variables were statistically significant at 0.01% level. In quantities harvested, both the endowment effect, i.e. the proportion of gap due to differences in observable characteristics between contract and non-contract farmers, and the coefficient or structural effect, i.e. the portion of the gap attributed to the returns of the same observable and unobservable characteristics were both positive and statistically significant at one percent and ten percent respectively. The endowment effect contributed about 93.1 percent [(0.463/0.497)*100] to the overall gap while 58.4 percent [(0.290/0.497)*100] was attributed to the coefficient effect. The gap was however lowered by the interaction effect by 51.5% [(-0.256/0.497)*100]. The interpretation of the interaction effect is however ambiguous since it captures both observable and unobservable effects. The positive and significant endowment and coefficient effects are indications that avocado contract farmers enjoy both endowment and structural advantage over their non-contract counterparts.

For quantities sold, the endowment effect accounted for 102 percent of the overall gap, implying that it was not the correlates of endowment that gave rise to the gap in quantities of avocados sold but the difference in endowment itself. The positive and larger endowment contribution may probably be because contract farmer asset levels are twice larger than non-contract farmers as indicated in the descriptive statistics. The decomposition result for avocado quality sold contrasted with those in quantities harvested and sold. Only the coefficient effect was statistically significant and accounted for 70.6 percent of the overall gap. The positive and significant large coefficient effect suggests that difference in avocado quality was mainly due to the structural disadvantages of non-contract farmers in returns to observable and unobservable characteristics.

The significant endowment effects in both quantities of avocados harvested and sold and the dominant significant coefficient effect explaining gap in avocado quality implies that even though equalizing resources between the two groups is a necessary condition for reducing the gap in quantities harvested and sold, it is not a sufficient condition for reducing the gap in avocado quality. Thus understanding the sources of these gaps is important for policies that would ensure avocado farmers receive adequate benefits from both endowment and the returns to their endowments. Detailed contribution of individual covariates presented in Table 2.10 sheds more light on the various effects.

Table 2.9: OLS Oaxaca-Blinder Aggregate Decomposition of Total Harvest, Sales and Quality

	Quantity harvested	Quantity sold	High quality grade
	Coef.	Coef.	Coef.
Mean prediction contract farmer	8.745***	8.535***	0.627***
	(0.065)	(0.084)	(0.031)
Mean prediction non-contract farmer	8.248***	7.957***	0.426***
	(0.052)	(0.074)	(0.023)
Difference	0.497***	0.578***	0.201***
	(0.083)	(0.112)	(0.038)
Endowment effects	0.463***	0.590***	-0.009
	(0.085)	(0.113)	(0.042)
Share of total gap	(93.2%)	(102.1%)	(4.5%)
Coefficient effects	0.290*	0.398	0.142**
	(0.168)	(0.253)	(0.075)
Share of total gap	(58.4%)	(68.8%)	(70.6%)
Interaction effects	-0.256	0.410	-0.050
	(0.256)	(0.254)	(0.077)
Share of total gap	(51.5%)	(-70.9%)	(24.9%)

Robust standard error in parenthesis *, **, *** Significant at 10%, 5% and 1%

Factors contributing to gap in quantities of avocados harvested

Result of factors contributing to widening of the gap in production outcomes between contract and non-contract farmers affirm the general thrust of decomposition result in Table 2.9. Analysis of factors contribution to the overall gap in quantities of avocados harvested in Table 2.10, shows a clear contribution of the number of productive *Hass* trees owned, total land owned, household member received training in avocado agronomy, fertilizer and pesticide application rate as well as grafting of avocado trees, hired labor and pruning of trees at least once a year to the endowment gap. The descriptive statistics lends support to the contribution of these variables in widening the gap between avocado contract farmers and their independent counterparts.

The positive and significant coefficient of *Hass* trees owned and household members received training in avocado agronomy showed that contract farmers are reaping higher returns from these endowments. On the other hand, the negative and significant effect of land owned, cost of transporting avocados to market and frequency of avocado group meeting attendance in the coefficient effect reduced the gap in quantities harvested. This suggests that non-contract farmers may have some structural advantage in quantities of avocados harvested. However, due to the statistically significant contribution of other variables to the endowment gap, its effect may not significantly lower the overall gap. This is consistent with the result in Table 2.9 which indicates a large and significant endowment effect in the overall gap. It is clearly observed from the results that differences in production outcomes between the two groups has so far been largely borne out of differences in inputs used and farmer's agronomic knowledge, *Has*s trees ownership and land. This result is plausible and in line with Tatlidi and Akturk (2004) who found that the number of seedlings and fertilizer usage significantly explained differences between tomato contract and non-contract farmers in Biga District of Canakkale Province, Turkey. The endowment gap is also consistent with most treatment effect literature on contract farming (Wainaina et al., 2012; Cahyadi and Waibel 2013; Warning and Key 2002).

Table 2.10: Factors Contributing to Net Gap in Quantities of Avocados Harvested

Variables	Endowment Effect Coef.	Coefficient Effect Coef.	Interaction Effect Coef.
No of productive *Hass* trees	0.150***	0.165**	0.104**
	(0.034)	(0.076)	(0.049)
No of productive *Fuerte trees*	-0.055	-0.119**	0.022
	(0.034)	(0.049)	(0.016)
Land owned (acre)	0.014**	-0.294***	-0.053
	(0.013)	(0.095)	(0.025)
Hired labor (yes=1)	0.036*	-0.230	-0.047
	(0.021)	(0.119)	(0.058)
Cost of transporting avocado to market (Ksh)	0.011	-0.230**	0.210*
	(0.010)	(0.119)	(0.112)
HH member received, training in avocado production (yes=1)	0.171***	0.489**	0.139**
	(0.056)	(0.207)	(0.061)
Group meeting attendance (no. in a year)	-0.013	-0.517***	0.133***
	(0.013)	(0.130)	(0.049)
Fertilizer and pesticide application rate (kg/tree)	0.033**	-0.058	-0.011
Grafted avocado tree(yes=1)	0.018**	0.204	-0.032
	(0.023)	(0.171)	(0.028)
Pruning of avocado trees (at least once a year (yes=1)	0.009*	0.020	-0.005
	(0.017)	(0.087)	(0.022)

Robust standard error in parenthesis *, **, *** Significant at 10%, 5% and 1%

Factors contributing to gap in quantities of avocados sold

Detailed decomposition results showing the relative magnitude of individual variables and their channel of influence on gap in quantities of avocados sold are shown in Table 2.10. The results indicated that the number of Hass trees owned, having hired labor to assist in marketing and receiving information on production and marketing were significant contributors to the gap. Notably, these variables also contributed to the gap in quantities harvested. This is an indication that there is a close linkage between the production and marketing processes. Low yields result in lower quantities sold and income. The positive sign of information received on production in the endowment effect and the negative sign in coefficient effect could mean that, although non-contract farmers maybe disadvantaged in terms of endowment to production and marketing information, they may have possibly benefited from spill-over effect of information flow which reduced the gap in quantities sold.

In the coefficient effect, years of educational, the number of productive Fuerte trees owned, and cost of transporting avocados to market were also favorable to non-contract farmers in reducing the gap. The significant effect of Fuerte in reducing the gap could be due to the current expansion of fruit outlets where the local Fuerte variety is mostly sold. The contribution of transport cost in lowering the gap could probably be because non-contract farmers mostly sell their produce at the farm gate thus accruing some advantage in terms of transport cost. Also in the case of land, non-contract farmers could have scale requirement where they could split their land for commercial avocado production and also produce other crops for sale or consumption. Hence, policy for enhancing avocado sales should focus on strengthening areas where non-contract farmers have relative advantage and thus closing the endowment gap

Table 2.11: Factors Contributing to Net Gap in Quantities of Avocados Sold

Variables	Endowment Effect Coef.	Coefficient Effect Coef.	Interaction Effect Coef.
Education of household head (years)	-0.024	-0.494**	0.023
	(0.019)	(0.249)	(0.020)
No of productive *Hass* trees	0.173***	0.110	-0.070
	(0.043)	(0.112)	(0.071)
No of productive *Fuerte* trees	-0.065	-0.139**	0.026
	(0.040)	(0.069)	(0.020)
Land owned (acre)	0.014	0.241*	-0.044
	(0.018)	(0.135)	(0.029)
Hired labor (yes=1)	0.057**	0.002	-0.001
	(0.029)	(0.115)	(0.088)
Cost of transporting avocados to market (Ksh)	0.015	-0.388**	0.354**
	(0.014)	(0.190)	(0.181)
Received information on avocado production & marketing (yes=1)	0.303***	-0.758***	0.215**
	(0.079)	(0.287)	(0.085)
Grafted avocado trees (yes=1)	0.006	0.510**	-0.080**
	(0.030)	(0.241)	(0.041)

Robust standard error in parenthesis *, **, *** Significant at 10%, 5% and 1%

Factors contributing to gap in quality grade of avocados sold

Table 2.12 reports results for drivers of the gap in the quality of avocados sold by contract and non-contract farmers. The age of the household, education, farming as main occupation, training received by household members and recording keeping on inputs and production were positive and significant in the coefficient or returns effect. The descriptive analysis in Table 2.2 showed that at 10 percent significant level, contract farmers were on average older than noncontract farmers. The difference in age endowment could perhaps reflect the returns to experience in avocado farming and quality produced by contract farmers. Although the descriptive statistics showed no statistical significant difference between contract and non-contract farmers in terms of education and main occupation, contract farmers had more years of education and more of them had farming as their main occupation. This perhaps also explains the difference in returns of these variables in contributing to the gap in the quality of avocados sold. Avocado agronomy training received by household members and keeping records on input used and production also positively contributed to the gap in the quality of avocados sold. This shows that enhancing human capital through training and extension services is essential for the quality of avocados produced and sold.

Table 2.12: Factors Contributing to Net Gap in Quality of Avocados Sold

	Endowment Effect	Coefficient Effect	Interaction Effect
Variables	Coef.	Coef.	Coef.
Age of household head (years)	0.016	0.591***	-0.017
	(0.011)	(0.211)	(0.011)
Education of household head (years)	0.009	0.265***	-0.014
	(0.007)	(0.098)	(0.010)
Main occupation of household head (farming=1)	0.001	0.182*	-0.003
	(0.003)	(0.107)	(0.005)
Land owned (acre)	-0.017*	-0.031	0.006
	(0.010)	(0.052)	(0.010)
Hired labor (yes=1)	0.022*	-0.020	0.015
	(0.012)	(0.039)	(0.030)
House member received training in avocado production (yes=1)	0.042	0.175**	0.121*
	(0.047)	(0.082)	(0.057)
Keeping records of input & production (yes=1)	-0.009	0.041**	0.025
	(0.008)	(0.021)	(0.014)

Robust standard error in parenthesis *, **, * Significant at 10%, 5% and 1%**

2.5 Summary, conclusion and policy implications

2.5.1 Summary

Smallholder avocado market participation through contract farming addresses simultaneous market constraints and serves as an important indicator that their production is neither limited to local market nor to their own consumption. The overarching objective of this study was to investigate factors influencing smallholder participation in avocado contract farming and underlying differences in mean quality and quantities of avocadoes harvested and sold by contract and non-contract smallholders. The essay used household survey data from Murang'a County in Kenya.

Based on a sample of 790 avocado farming households, 266 were contract and 524 non-contract farmers, the descriptive statistics indicated a significant difference between the two groups in their knowledge of agronomy in fertilizer and pesticide application, tree grafting, frequency of avocado meeting attendance, costs of marketing avocados as well as in physical and financial endowments. Besides the age of the household heads, other demographic characteristics were not significantly different. The essay used the probit model to investigate factors influencing smallholder participation in avocado contract farming. Marginal effects from the probit estimates suggested that the age of household head, number of mature *Hass* trees owned, household assets, hired labor, cost of transporting avocados to market, provision of production and marketing information, frequency of avocado meeting attendance and training received in avocado agronomy, were positive and significant predictors of smallholder avocado contract farming.

Further, differences between contract and non-contract farmer groups were examined by analyzing mean differences in quality and quantities of avocados harvested and sold using the Oaxaca-Blinder decomposition approach. Selection bias was controlled for using the inverse Mills ratio. This ratio was however statistically insignificant; hence the null hypothesis of selection bias into contract farming was rejected necessitating the use of Oaxaca-Blinder decomposition OLS estimator. Results show that the endowment gap largely contributed to the overall gap in both quantities of avocados harvested and sold between contract and non-contract farmers while the gap in quality of avocados sold was solely due to differences in returns to endowments.

Detailed decomposition to unravel factors contributing to the gap showed that the number of *Hass* trees and land owned, hired labor, training in avocado agronomy and their application such as tree grafting, fertilizer and pesticide application and tree pruning as well as received information on production and marketing significantly contributed to widening the gap in the quantities of avocados harvested. For quantities sold, the number of *Hass* trees owned, hired labor and information on production and marketing contributed to the endowment gap. Non-contract farmers, however had some structural advantage in terms of land owned, cost of transporting avocados to market and frequency of avocado group meeting attendance which lowered the gap between the two groups in quantities harvested and sold. For the quality of avocados sold, decomposition revealed that farmers' demographic characteristics such as age, education and main occupation along with training in avocado agronomy and record keeping on input use and production contributed to the gap in the returns to endowment effect.

2.5.2 Conclusion

This essay has empirically analyzed determinants of participation in smallholder avocado contract farming and differentials in production outcomes between contract farming and non-contract farmers in Kenya. Result showed that several policy variables were significant in explaining the two. Based on the probit model, the result indicated that the number of *Hass* trees significantly influenced participation. This finding revealed that smallholder linkage to the value chain through contract farming depends on the number of trees owned which in essence also determines the viability and sustainability of the sector.

The positive relationship between household assets and contract farming suggested its complimentary role in input acquisition. Results also indicated that hired labor for avocado production and marketing significantly influenced contract participation. With the existence of significant level of unemployment and under-employment in the rural areas, avocado contract farming has the potential to absorb some surplus labor, and by using that labor force, the country has an opportunity to improve its' economy and the welfare of rural dwellers. This finding supports Begum et al., (2013) who found hired labor to be an important factor influencing participation in smallholder poultry contract farming in Bangladesh.

Training in avocado agronomy and information on avocado production and marketing were positive and significant factors influencing contract participation. Building avocado farmers capabilities through training and the provision of production and marketing information provide guidance to farmers in planning production and harvest dates, fertilizer application, pest control as well as price and buyer information. Such information helps in the assurance of avocado quality and premium price for farmers (Man and Nawi, 2010). The cost of transporting avocados to market played a significant role in contract participation. Transportation cost is one of the major reasons smallholder farmers sell their avocados at the farm gate to brokers. These brokers usually dictate the farm gate price since they bear the cost of transporting the fruit to market. As such, farmers end up receiving relatively small amount for the fruit. Contract farming significantly reduce transportation costs for farmers since farmers most often assemble their produce at a designated center for pick up by the contractor. This finding is consistent with findings from Leung et al., (2008) on rice contract farming in Lao PDR.

The frequency of avocado meeting attendance played a vital role in the likelihood of smallholder contract farming. Farmer group serves as an important channel for the dissemination of knowledge on production practices as well as new technologies. Thus, the active participation of group members through the frequency of meeting attendance is a signal of group cohesion and sustainability which provides a solid platform for farmer's participation in contract farming. Besides, most contractors prefer contracting with groups that are active since it reduces monitoring cost.

Gap analysis from the Oaxaca-Blinder decomposition for avocado quality and quantities of avocados harvested and sold by contract and non-contract farmers, revealed that a large portion of the gap in quantities of avocados harvested and sold were mostly explained by the endowment effect while the gap in avocado quality was due to the coefficient effect or returns to endowments. This suggests that interventions aimed at enhancing smallholder avocado commercialization should go beyond resource equalization to encompass programs that would enable non-contract farmers obtain returns from endowments like their contract counterparts.

Our study established that differences between contract and non-contract farmers in quantities of avocados sold and harvested were due to differences in the number of *Hass* trees owned, hired labor, size of land owned, training in avocado agronomy training and practices and the provision of production and marketing information. Gap between the two groups in avocado quality was explained by demographic factors such as education and main occupation, age, as well as training in avocado agronomy and record keeping on input use and production. Hence, addressing both the resource gap and the returns to endowments could help non-contract farmers reap maximum benefits from avocado production as their contract counterparts. This study has provided empirical evidence not only of drivers that influenced avocado contract participation but also the source of the gap and factors that contributed to the gap in participation.

2.5.3 Policy implications

A number of policy issues arise from the findings of this study. Evidence from our study revealed that number of *Hass* trees owned is a significant predictor of contract participation. It is recommended that the county government harnesses the opportunity of the growing demand for *Hass* variety by promoting its cultivation. This can be done by sensitizing farmers on the importance of adopting the variety and by also helping them to acquire planting material, such as grafted and certified avocado seedlings. Increasing the number of *Hass* trees will not only enhance avocado contract farming but also ensure supply of the fruit which will have a multiplier effects along the chain for the farmers, exporters and processors.

Grafting technique contributed to the widening of the gap in quantities of avocados harvested and sold by contract and non-contract farmers. The gap in farmer's agronomy knowledge in grafting, pruning and fertilizer application rate and training in avocado agronomy can be closed by government's support in building farmer's capabilities in agronomy through extension workers. A step could be taken further to help farmers establish nurseries individually or collectively. These measures would ensure the sustainability of avocado production and more smallholder participation in contract farming and hence boost the value chain.

Our research findings also indicated that hired labor for avocado production and marketing played a significant role in contract participation. This is an indication that the increasing demand for avocados provides a positive future outlook for the sector and employment opportunities. Policy makers should therefore ensure a wider scope of smallholder participation in avocado contract farming. Land size significantly contributed to the endowment gap in quantities of avocados harvested between contract and non-contract farmers. Since the availability of arable land is limited, government should consider the option of investing in semi-arid or arid land by building irrigation systems in areas that could be feasible for avocado production. Although such investment may be costly, the long run benefits of investing in a crop with growing market demand will outweigh the cost.

The provision of information on production and marketing significantly influenced avocado contract farming. This again suggests the need for active and interactive farmer-extension service policy design and an innovative system of information dissimilation on new production techniques, marketing channels and prices. Frequency of avocado group meetings attendance also influenced the likelihood of participation in contract farming. Meeting attendance by farmers serves as important medium of social capital. Group cohesion builds farmer's confidence in contract farmer and helps them make credible commitments to contract agreements. Thus local authorities should encourage and provide support to existing farmer groups to ensure active participation of members in the groups. The formation of such groups in communities where there are none is encouraged.

Finally, cost of transporting avocados to the market motivate farmers to participate in contract farming, hence, development of rural infrastructure provides a more direct and cost effective means of transport for farmers to market their avocados. It will also facilitate the timely delivery of avocados to the market which helps preserve the quality of the fruit.

CHAPTER THREE: QUANTIFYING GENDER PATTERNS IN LABOR ALLOCATION TO AVOCADO PRODUCTION IN KENYA

3.1 Introduction

The effective participation of men and women farmers in agricultural production, especially for crops with high market potential, has been recognized as a means to attaining gender equity, reducing rural poverty, and ensuring the sustainability of agriculture (OECD, 2008). The avocado crop has growing national and global demand and the potential to provide employment opportunities and a stable source of income for smallholder farmers. Kenya is an important exporter of avocados (mainly *Hass* and *Fuerte* varieties) in the European market with 85 percent of all export fruit being produced by smallholder farmers (HCD, 2016). The country has a competitive advantage over other countries also dealing in the *Hass* variety for which the harvesting season falls when none of the leading producers have fruit. The opportunities available for both men and women producers makes the crop ideal for rural poverty reduction.

However, gender related issues in production are of particular concern to the development of crop agriculture since women and men are differently endowed and experience different vulnerabilities which may impact production outcomes and the well-being of their households. Utilizing the potential of agriculture as a tool for poverty reduction, food security and sustainable development requires understanding gender roles and responsibilities in crop production. Several empirical studies have presented compelling evidence that gender affects resource ownership, tasks, productivity, decisions on production and utilization of income from production (Doss, 2002; Kilic et al., 2015), and addressing these gender based constraints has been renewed policy focus of governments and development partners.

Avocado production activities in Kenya are mostly done by men and women. However, tasks and responsibilities follow traditional gender roles with males performing labor intensive tasks such land preparation, spraying, pruning and harvesting (which requires tree climbing) while women are involved in grafting, weeding, post-harvest activities and the general management of trees. Avocado trees are mainly owned by heads of households who in most cases are males. As owners of the trees, they make production, marketing and income decisions and also negotiate avocado contract farming agreements for those under contract farming. Studies by Oduol et al., (2014) and Mutiso, (2017) noted the dominance of males in avocado farmer's group and in the avocado export chain. According to these studies, the poor participation of women farmers was due to their lack of ownership right to the trees, which limits their participation in avocado farmer groups and from the benefits of avocado agronomy and good agricultural practice (GAP) trainings. Oduol et al., (2014) further indicated that although women participate in production, their role was not fully recognized by other chain actors due to lack of ownership rights to avocado trees. The exclusion of women farmers is affirmed by Dolan (2001) whose study of French beans in Kenyan indicated that production value chains involving commercialization tend to exclude women even where they are the main farmers.

The commercialization of avocados depends on the intensity of production which is highly dependent on family labor. However, analysis of household labor patterns and the allocation of tasks and time to production seem to be neglected in empirical research. With the growing market and export potential of the fruit, promoting gender inclusive participation and opportunities requires understanding gender patterns in production and factors that constrain their labor allocation behavior. Moreover, Kenya's avocado export potential in terms of meeting quantity requirements to maintain market share in face of global competition depends on the efficient and effective participation of male and female farmers in production, thus, strengthening production and marketing systems for the sustainability of the avocado sector requires disentangling the gender effect of the respective roles played by each gender. This permits a rich analysis of how their roles may differ by activity. It also provides a channel for opportunities that can be harnessed to improve their participation and innovative policies that could address gender related constraints.

The effects of globalization coupled with economic and social transformations as well as migration of male farmers in search of off-farm opportunities have substantially shaped the reorganization of household forms, and specifically the gender division of labor and responsibilities in crop production in Kenya (Eerdewijk and Danielsen (2015). These dynamisms may likely influence the availability of labor to perform critical tasks in avocado production. The implication is that ensuring the active participation of women farmers at all levels of the avocado production cycle requires an understanding of how these relationships affect gender patterns in production.

Previous studies (Fischer and Qaim, 2012; Oduol et al., 2017) have shown that due to lack of access to productive resources, women farmers were increasingly disadvantaged from enjoying the benefits of agricultural commercialization, which further pushes them to higher levels of poverty. Since women allocate labor to avocado production and trees are mainly owned by males, analysis of roles and responsibility each gender play in production could flag the important role of women in avocado production. Such analysis could inform appropriate strategies that can be put in place to properly integrate women in the avocado chain so that they can benefit from avocado commercialization.

3.1.1 Problem statement

Gender differences in crop production remain a strong factor that presents binding constraint to the growth of agriculture if polices are not well tailored. The importance of this message was brought to the fore by Collier (1993) who demonstrated that the prevalent gendered division of labor hampered the adoption of tea cultivation in Kenya. Structural changes such as increasing commercialization, male migration, and demand for non-traditional exports like avocado in the Kenyan agricultural sector, have resulted in a paradigm shift where traditional gender roles once performed by men are now performed by either women or by both genders. This dynamism in the realignment of household labor is usually accompanied by opportunities and constraints. Failure to distinguish between gender differences in production and its interlinkages in other economic activities could lead to blanket policy prescriptions that may not address gender differences and constraints.

Previous studies have investigated different aspects of avocado production and marketing. For instance, Gyau et al., (2016) analyzed the factors that determine collective action and how this in turn influences avocado production and marketing. Omolo et al., (2011) investigated avocado marketing in Trans-Nzoia district, while Oduol et al., (2014) investigated women's participation -

in the avocado value chain in Kandara and Marani using value chain analysis. These studies investigated linkages within the avocado value chain, but the primary issue of production and structural changes within the household, which may hamper production of the fruit and resulting market participation, have not been addressed. This study positioned itself to fill the gap by investigating gender patterns in labor allocation to avocado production and other economic activities as well as the intensity of time use.

The point of departure of this essay from other studies is its contribution to gender, agriculture and labor literature by firstly using a framework that models gender differences in labor allocation to avocado production as well as to other off-farm activities as a two stage procedure of participation and intensity of participation. Secondly, this study explicitly accesses the role of avocado contract farming on gender labor allocation. Thirdly, this analysis informs policies related to opportunities and constraints experienced by male and female avocado farmers for which appropriate interventions can be planned.

3.1.2 Research questions

The study addresses the following questions:

i) What factors explain gender patterns in labor allocation to avocado production and other economic activities?
ii) What is the intensity of time use in these activities by gender?
iii) What is the role of avocado contract farming on gender labor allocation?
iv) What policy options can be put in place to address gender related constraints in avocado production?

3.1.3 Study objectives

The overall objective of this study was to analyze gender patterns in labor allocation to avocado production.

The specific objectives include:

i) To investigate factors that explain gender patterns in labor allocation to avocado production and other economic activities

ii) To analyze the intensity of time use in these activities by gender.

iii) To assess the role of avocado contract farming on gender labor allocation.

iv) To make policy recommendations on gendered labor allocation based on research findings.

The rest of the essay is organized as follows: Section 3.2 presents theoretical and empirical literature on gender patterns in labor allocation. Section 3.3 presents methodology, data and descriptive statistics. Section 3.4 presents results and discussion while section 3.5 presents summary, conclusion and policy implications.

3.2 A review of literature on gender patterns in labor allocation

3.2.1 Section overview

This section presents both theoretical and empirical literature on factors influencing gendered labor allocation. Subsection 3.2.2 presents theoretical foundation of intra-household labor allocation; 3.2.3 presents empirical literature review of gender differences in labor allocation; while 3.2.4 provides summary of literature review.

3.2.2 Theoretical foundations of intra-household labor allocation

The theoretical foundation of gender division of labor within the New Institutional Economics theory framework is based on Becker (1962) human capital theory, which indicates that the difference in male and female labor allocation behavior is attributed largely to differences in the market valuation of their human capital, which in turn reflects their productivity in the market. Becker's work laid the framework for the non-separable agricultural household model (Singh et al. 1986) widely used in empirical research. There are other competing theories such as Bargaining (Chiappori, 1988; McElroy and Horney, 1981) and Norms and Institution (Akerlof and Kranton, 2000) that explain the gendered division of labor within the household. This study adopted a unitary model framework in which farm households make both consumption and production decisions simultaneously (Singh et al., 1986). The novelty of the unitary model is its integrability property which allows structural models to be recovered from observed behavior (reduced form).

Moreover, in most rural settings division of work is governed by cultural norms rather than household bargaining (Jones, 1986). Akerlof and Kranton (2000) observed that in most instances, social role rather than economic forces explain differences in time allocation. It is highly plausible that in our study area, intra-household division of labor is motivated by gender considerations rather than bargaining, hence our choice of model.

3.2.3 Empirical literature review of gender patterns in labor allocation

The gender inequality gap was first articulated by Boserup's 1970 study of women's role in agriculture. She argued that women were not benefitting from agricultural production due to the type of cultivation system used. The study described women's farming as labor intensive and producing only for subsistence consumption while male farmers used capital intensive methods to produce cash crops for export markets. Boserup pointed out that the distinction in production resulted in exclusion of women from the exports market thus perpetuating marginalization and poverty of women.

Following concerns of gender inequality in agriculture, various empirical studies have been done to establish factors that influence how labor and other household resources are allocated between home, farm and off-farm activities. Fafchamps and Quisumbing (2003) used panel data to investigate the relationship between human capital, learning by doing, social roles and intra-household division of labor within rural households in Pakistan. Using proxies such as gender and family status for social roles, age education and child nutrition for human capital, they found that gender and family status significantly influenced intra-household labor allocation to various activities. Male members allocated more labor time to activities that generate income while females were in charge of home production activities. Results from the Tobit regression showed that gender and family status significantly influenced total amount of family labor as well as individual share of labor allocated to farm and off-farm activities. The study however considered participation and intensity time used as a single stage decision which is not always the case. The current study contributes to the literature by analyzing gender differences in both participation and intensity as separate decisions.

Ilahi (2001) used panel estimation technique to estimate the determinants of male and female time allocation to various activities in Peru. Findings established that age, marital status, and ethnicity significantly influenced how time was allocated to various activities. The study further indicated that women spent most of their time doing housework while their male counterparts spent theirs in non-farm income generating activities. The author concluded that although economic variables significantly influence differences in male and female time allocation, the effects of social norms cannot be ruled out although it is difficult to pinpoint variables that capture norms which influence behavior.

In the same vein using Tobit estimation, Schindler (2008) analyzed time allocation to both farm and non-farm activities in relation with gender and norms in post-war genocide Rwanda. Regression results showed that for households headed by widows, adult male members spent more time on income-generating activities than in domestic activities. Land ownership used as a proxy for decision making was found to be highly significant for farm activities for both male and widow household heads, educational attainment and wealth status significantly lowered the intensity of household labor allocation to agricultural activities. Like Fafchamps and Quisumbing (2003), Schindler (2008) also used the Tobit model which assumes participation and intensity decision as the same process.

Sikei et al. (2009) estimated a system of equation model for fuel wood collection, agriculture and non-farm activities using seemingly unrelated equation in Kakamega forest, Kenya. Their findings indicated that education, landholdings, distance and household size were significant in explaining household labor allocation decisions. The signs of these effects however varied across activities. The study however did not account for social norms which have been found to significantly influence gendered labor allocation decisions. Moreover, simultaneous modeling of labor allocation relies on coherence conditions whose failure could lead to large over adjustment for simultaneity bias (Blundell and Smith 1989). This study corrects for these pit falls by using variables that capture social role and also use maximum likelihood estimation technique that requires only an explicit linear form with no coherence condition to achieve unbiased estimates.

Studies specifically investigating the various facets of avocado production include Shumeta, (2010). The study employed descriptive analysis to investigate the production and marketing of avocado in Southwestern Ethiopia. Mean statistics of household characteristics of avocado farmers indicated that avocado was mainly produced by older farmers with some minimum level of formal education. There were indications that farmers on average had the same amount of land holdings and that these farmers were primarily employed in on-farm production. The study further investigated the socio-economic importance of the crop among producers and concluded that avocado production contributed significantly to the livelihood of smallholders involved in its production.

Similarly, Omolo et al., (2011) investigated market dynamics and challenges in avocado production in Trans-Nzoia district in Kenya using descriptive analysis. Their findings indicated that the majority of avocado farmers sold their avocado to middle men or brokers who paid relatively lower prices and that lack of marketing information, reliable markets and transport systems were among major constraint experienced by farmers. These studies provide information on avocado production benefits and related challenges. However, with the use of descriptive analysis, the findings cannot be easily replicated nor generalized. Moreover, these studies did not incorporate gender differential in their analysis.

Oduol et al., (2014) conducted a gendered value chain analysis on the level of participation of women in both male and female headed households in the domestic and export avocado value chain in Kenya. The authors indicated that women were more dominant along the production chain while their male counterparts were mostly visible along the marketing chain. They also indicated that women in female headed households face some constraints with regards to physically demanding activities like harvesting and specialized skills such as grading and spraying. Also, Gyau et al., (2016) used probit model to analyze the determinants of participation in avocado farmers group which carries out collective actions such as sales, training, processing and borrowing. Their result suggests that the age of the farmer, education and being a male farmer positively influenced avocado group participation. The study of Oduol et al., (2014) and Gyau et al., (2016) brings out salient information on gender relations and interactions along the avocado value chain as well as membership into avocado groups. However, these studies could have been more informative if labor allocation decisions were also analyzed. This research fills in this gap by analyzing gender patterns in labor allocation in avocado production and the intensity of labor allocation.

Other groups of studies have been focused on gender dynamism in various crop production activities and crop types. For instance, Kiriti and Tisdell (2002) investigated the effect of women's marital status on cash cropping in Nyeri district Kenya. Using multiple regression analysis, the authors asserted that in male headed households, wives were mostly involved in food crop production but allocated more labor time to the production of cash crops owned by their husbands. Their study concluded that the continued deterioration of trade in cash crop production would result in more male involvement in food crop production leading to the potential crowding-out of women in food production.

Qualitative case study analysis conducted by Eerdewijk and Danielsen (2015) for maize production in Ethiopia and Kenya found that men's involvement in agriculture is changing and declining. Women in the study sites reported that due to the migration of men, farming tasks previously performed by men are now performed by women. The study further revealed that in female-headed households, tillage, land preparation, weeding, post-harvest management and transport are done by female members of the household. The authors also indicated that hiring labor and animal drafts are the most common ways of reducing labor burdens. The study of Kiriti and Tisdell (2002) would have been more interesting if it had included household labor allocated to other economic activities since labor allocation to crop production and other economic activities are interconnected, while the generalizability of qualitative analysis by Eerdewijk and Danielsen (2015) is problematic. Our study accounts for the omissions by analyzing gendered labor allocation to both farm and off-farm activities using two stage estimation procedures.

Palacios-Lopez et al., (2015) investigated how much labor women farmers contributed to agricultural activities in several countries in sub Saharan African. Controlling for the knowledge of the respondent and gender for possible proxy response bias, estimates showed that female labor share in crop production averaged around 40 percent but country wide estimates varied. The intensity of involvement of women in cash crop production also differed across countries. Further investigation into factors that affect female labor allocation to crop activities found no clear dissimilarity in female labor share across agricultural households. A consistent pattern that was however noticed across some countries was the intensification in female labor when women were more educated and owned land. The authors however cautioned that due to reporting bias by proxy informants on labor contribution, results provided by the inclusion of these covariates should not be taken as causality in estimation but rather as an exploratory guidance.

3.2.4 Summary of literature review

The review of theoretical literature on household labor supply shows that the theory of labor supply and demand has been improved on over time from the basic classical theory to the incorporation of women and inter-household resource allocation and finally market failure in the labor supply model. On the empirical literature review, various studies have indicated that a number of factors influenced gender participation in production. For instance bargaining power proxied by asset ownership; land and non-land assets; hired labor, crop type (cash crop or subsistence crop), household headship and gender roles. Activities such as planting, harvesting, weeding, processing and marketing were performed by women while men were involved in tillage and land preparation with these roles changing over time.

The review also shows that descriptive and qualitative methods as well as ordinary least squares, systems of equation and Tobit models were mostly used. The draw back in these approaches is that the generalizability of the descriptive and qualitative analysis is problematic while ordinary least squares and systems equation are not ideal for estimating censored dependent variables. On the other hand, although Tobit models are suited to handle zero observations on the dependent variable, its key limitation is the assumption of time allocation and intensity decisions as a single process. This study addresses these limitations and contributes to gender literature by using two stage estimation procedures to investigate factors that influence gender patterns in participation and intensity decisions in avocado production and other economic activities under contract and non-contract scenarios.

3.3 Methodology

3.3.1 Section overview

The methodology section presents both the theoretical and empirical methods employed in this essay. Subsection 3.3.2 provides the theoretical model; 3.3.3 presents the empirical model while 3.3.4 presents definition and measure of variables.

3.3.2 Theoretical framework for gender differences in farm labor allocation

This essay models household labor supply decision within the unitary model framework in which consumption and production decisions are made simultaneously (Singh et al., 1986). Following Fafchamps and Quisumbing (1999), the household welfare maximization problem, subject to constraints imposed by resource endowment, household time, and production technology can be written as:

$$\sum_{i=1}^{N} U^i \omega^i (C_z^i,\ C_m^i,\ Z^h, T^i - L^i) \tag{3.1}$$

where U^i represents individual utility well-defined over consumption and leisure; ω^i refers to welfare weights treated as exogenous to the labor allocation process (Alderman et al., 1995); C_z and C_m are vectors of home and market-produced goods respectively; Z^h refers to household characteristics; and T^i and L^i refer to total time and labor endowments respectively allocated to various activities. The household maximizes welfare subject to a production function that is expected to be a function of home consumption and marketable goods Q_m and C_z respectively; L_a^* is adult male and female labor allocated to land preparation, weeding, harvesting, and marketing using inputs K_k, and H represents household and human capital variables which expresses the effectiveness of labor in each activity. Adults may get involved in other economic activities such as wage employment and non-farm self-employment to earn wage and profits. They may also hire labor to substitute for individual or family labor. These economic activities are subsumed into the function G as distinct activities represented as:

$$G(Q_m, C_z, L_a^*, K_k, H^i) \geq 0 \tag{3.2}$$

Considering that market transactions occur at a set of market price, the budget constraint which the household faces can be specified as:

$$\sum P_m(Q_m - C_m) + A = Y \tag{3.3}$$

where Y is full income composed of farm profits and non-labor income A. The solution to the household welfare maximization problem equation (3.1) which is subject to equations (3.2) and (3.3) and non-negativity constraints, $L_a^* \geq 0$, gives the reduced form labor supply functions (de January et al. 1991) as:

$$L_a^* = f_a(K_k, Y, H_1, \ldots H_N, \omega_1, \ldots \omega_N) \tag{3.4}$$

Where $\omega's$ are welfare weights. By aggregating the reduced form labor allocation function L_a^* over N individuals in the household, total labor time used yield the following equation:

$$L_a = F_a(K_k, Y, H_1, \ldots H_N, \omega_1, \ldots \omega_N) \tag{3.5}$$

Equation (3.5) forms the basis of our empirical analysis and can be estimated econometrically for all households by substituting individual variables H_1 and ω_1 with household and individual variables potentially affecting welfare weights. Control variables such as household characteristics, physical and financial endowments, social capital, and distance to markets are postulated as potential channels through which participation and intensity decisions are influenced (Fafchamps and Quisumbing 2003; Ilahi 2001).

3.3.3 Empirical model specification

Within this sub-section, econometric model for the likelihood of male and female participation in avocado production and other economic activities coupled with level of participation is presented. Based on the reduced form equation (3.5) separate labor supply functions were estimated for adult males and females for labor time allocated to avocado production and other economic activities. We hypothesize that limited credit access and the presence of young children in the household constrain female participation and time use in avocado production and other economic activities For the identification of our variables of interest, we included various control variables such as household characteristics, physical and financial endowments, social capital and distance to market postulated as potential channels through which participation and intensity decisions are determined (Fafchamps and Quisumbing 2003; Ilahi 2001; Schindler 2008; Sikei et al., 2009; Su et al.. 2016). Following discussions above, the determinant of labor time allocation can be written as:

$$L_{ai} = X_{ai}'\beta + \varepsilon_{ai} \tag{3.6}$$

Where L_{ai} is the dependent variable representing the share of household labor allocated by males and females to avocado production, other farming activities, wage and non-farm self-employment, X_{ai} is set of covariates which includes household and individual characteristics, physical and financial endowments, social capital and community characteristics β is a vector of parameters to be estimated and ε_{ai} is the stochastic error term assumed to be distributed normally.

Typically, the interdependence in household decision making among inter-related activities, warrants the estimation of the labor supply function (equation 3.6) through a system of behavioral equations using ordinary least squares (OLS) Meng et al., (2014). Zellner (1982) however proposed that the Seemingly Unrelated Regression (SUR) which allows the joint estimation of dependent variables as a group but with no theoretical interdependence among the dependent variables creates more efficiency gains than those obtained from the equation-by equation estimates. Some studies (Sikei et al., 2009) have used the SUR to estimate household labor allocation decisions. The problem with the systems procedure is that these systems of equation are an extension of OLS which assumes complete participation. Ideally, individuals in farm households often make decisions on which activities to allocate their time and how much time to spend. Consequently, there end up being activities with no time allocated to them thus causing the dependent variable to be constrained with some clustering at zero. Thus OLS estimation of equation (3.6) on the complete sample as well as on the unclustered part is biased and inconsistent (Wooldridge, 2002).

The Tobit is the standard approach used in most time allocation studies to circumvent the issue of zeros in the dependent variable (Fafchamps and Quisumbing 2003; Schindler 2008). The model permits the estimation of censored dependent variables by combining both probit and OLS models to demarcate non-participants and participants to assess the behavioral characteristics of participants. The Tobit model is however restrictive in the interpretation of coefficients. For instance, in time use studies, the assumption of the Tobit model is that participation and intensity decision are made as a single process, implying that variables that increase the likelihood of participation also increase the level of hours worked which in principle may necessarily not be the case since participation and intensity decisions can be made separately or jointly (Berhanu and Swinton 2003).

A further deficiency of this approach is that zero hours of labor time are interpreted as a corner solution. This assumption is limiting for our analysis because in our study it is reasonable to assume that individual's time use in avocado production and other activities could be due to economic, social, demographic and cultural concerns. For instance, individuals may not allocate time to some activities in avocado production because activities may be divided within the household along the production chain by age or gender considerations. Likewise, time allocation to other economic activities may be due to individual preference and ability or qualification. These drawbacks in addition to its normality and homoscedasticity assumptions (Cameroon and Trivedi, 2010), motivates our use of a two tier model with much flexible assumptions.

The generalized version of the Tobit (double hurdle) model proposed by Cragg provides an alternative and suitable frame work for our study. This is because it relaxes the Tobit assumption and models participation and intensity decisions as separate stochastic processes. It is also more flexible than the Heckman (1979) two stage procedure since it allows for the possibility of zeros in both outcomes (Cameroon and Trivedi, 2005). Innocent and Young, (2004) has shown that although the double hurdle approach has been widely applied to migration and agricultural technological adoption studies (Simtowe and Zeller, 2007), it is also suitable for labor supply decisions studies.

3.3.3.1 Double hurdle model specification

The double hurdle model (Cragg, 1971) was adopted in this essay to correct for the econometric challenges discussed above. The assumption of the model is that an individual must cross two hurdles before being observed as allocating positive hours of work for each activity; hence, if we observe a positive decision of participation for a household member in each activity, then that individual crosses the first hurdle (participation). Crossing the second hurdle entails that condition on participation, we should observe positive hours of work allocated to the various activities for that individual (intensity). The model assumes that the hurdles are linear in parameter and that the utility derived from these decisions are determined by different latent variables. The time decision is modeled as probit while the level of time in each activity is modelled as a Tobit. Following (Jones 1989 and 1992) the three components of the double hurdle model representing participation and intensity equations as well as observed labor days is specified as:

Participation decision (first hurdle)

$$Y_{1i}^{*} = z_i^{'}\alpha + \varepsilon_i \tag{3.7}$$

$$Y_{1i}^{**} = 1[Y_{1i}^{*} > 0] \tag{3.8}$$

Intensity decision (second hurdle)

$$Y_{2i}^{*} = X_i^{'}\beta + u_i \tag{3.9}$$

$$Y_{2i}^{**} = \max(0, Y_{2i}^{*}) \tag{3.10}$$

The two hurdles are linked to give the share of observed labor days (Y_i) allocated to each activity specified as:

$$Y_{ai} = Y_{1i}^{**} Y_{2i}^{**} \tag{3.11}$$

where Y_{1i}^{*} denotes the latent variable representing utility derived from participation in each activity, Y_{1i}^{**} is participation hurdle, where one denotes participation and zero otherwise, Y_{2i}^{*} represents the latent variable signifying the utility gained from time allocated to each activity, Y_{2i}^{**} is the intensity hurdle denoting the latent share of labor time allocated to each activity, Y_{ai} is observed share of labor time allocated to activities ‘ a ’ (i) avocado production, (ii) other crops production, (iii) wage employment, (iv) non-farm self-employment; by individual i. Z and X are vectors of covariates including individual and household characteristics, (N) a vector of physical and financial endowments, (O) social capital and (P) other variables that influence participation and level of time use. α and β are parameters to be estimated while ε_i and u_i are error terms which are randomly distributed as bivariate normal distribution. The assumption of uncorrelated errors earlier made by (Cragg, 1971) have however been relaxed in later work (Jones, 1992) to incorporate a correlation coefficient ρ which results in a model specification with dependent error terms in a double hurdle.

$$\begin{pmatrix} \varepsilon_i \\ u_i \end{pmatrix} \sim N(0, \sum), \ \sum = \begin{pmatrix} 1 & \rho\sigma \\ \rho\sigma & \sigma^2 \end{pmatrix} \tag{3.12}$$

Assuming a dependent relationship between participation and the level of time allocated through correlated error terms, which permits the two decisions to be made simultaneously, and then denoting zero labor allocation as 0 and positive amount of labor time as +, the likelihood used for the double hurdle model can be expressed as in Jones (1989 and 1992):

$$L = \prod_{0}\left[1-\varpi(z_i^{'}\alpha, \frac{x_i\beta}{\sigma}, \rho)\right]\prod_{+}\left[\Phi\left(\frac{z_i^{'}\alpha + \frac{\rho}{\sigma}(y_i - x_i\beta)}{\sqrt{1-\rho^2}}\right)\frac{1}{\sigma}\phi\left(\frac{(y_i - x_i\beta)}{\sigma}\right)\right] \quad (3.13)$$

Where $\varpi(.)$ is the bivariate normal cumulative distribution function (CDF), $\Phi(.)$ is the conditional CDF, $\phi(.)$ is the univariate normal probability density function (PDF), ρ, β, σ and α are parameters that can be estimated simultaneously. If the correlation coefficient ρ =0, the model becomes similar with Cragg's independent double hurdle. If on the other hand ρ =0, $x = z$ and $\alpha = \beta/\sigma$, then with no censoring or selection present, the double hurdle model reduces to a Tobit model which is the sum of the log likelihood of the probit model representing the first part and truncated normal regression model the second part.

The double hurdle model is typically estimated by Maximum Likelihood (ML) methods, since analytical expressions for the Hessian matrix and the score vector are readily derived. The bivariate normality assumption of the error term in equation (3.12) is however crucial for the consistency of ML estimation to hold (Newman et al. 2003). While the DH models with bivariate errors have been widely used, Smith (2003) shows that assuming dependency between the two equations is not a worthwhile exercise as there is little statistical information available to support dependency in a DH framework. The authors argue that this is why most studies were unable to support the existence of dependent parameter under the assumption of the independence between the two stochastic errors.

Gao et al., (1995) supported this argument by suggesting that the violation of the homoscedastic, normally-distributed, errors assumption might be the primary suspect for the inconsistency of maximum likelihood parameter estimates in the dependency assumption. Approaches used to correct for non-normality have been either to transform the data or impose a different distribution. The Box-Cox transformation, which include logarithmic transformation as a limiting case suggested by Poirier (1978) have been used by some studies to deal with the problem of non-normality. Findings by Maddala (1983) however showed that the Box-Cox transformation is not defined when the latent variable is not positive.

Alternative approaches such as the univariate inverse hyperbolic sine transformation, continuously defined over positive, negative and zero values was suggested by Burbidge et al., (1983), while Cragg (1971) on the other hand suggested an imposition of non-normal distribution such as log-normal distribution. The method of handling the non-normal distribution has however not been conclusive. This study used the natural logarithmic transformation to handle positively skewed data following Newhouse (1987) and Wagner and Hanna (1983). With the natural log transformation, the positive time allocated remains positive while zero time allocation without transformation remains as the truncated part. Transformation of the dependent variable to the natural logarithm form is more responsive for the computation of elasticities than other non-linear transformations (Newhouse, 1987).

In order to assess the effect of the explanatory variables on the outcome variable, three marginal effects were calculated. These include: i) the probability of allocating time to various activities ii) the expected level of time allocated (the unconditional expected mean showing the total effect on the explained variable) and iii) the expected level of time allocated based on participation (conditional expected mean). These marginal effects were calculated for each activity separately for males and females based on coefficients of the double hurdle model following (Yen, 2005). The odds of participation in each activity (i.e., a positive observation) which depends on both participation and intensity parameters can be written as:

$$\Pr(y_i > 0) = \varpi(Z_i^{'}\alpha, X_i^{'}\beta / \sigma, \rho) \qquad (3.14)$$

The unconditional mean decomposed into two parts can be specified as:

$$E[y_i] = p(y_i > 0) * E(y_i \mid y_i > 0) \qquad (3.15)$$

Where $p(y_i > 0)$ is the probability of participation and $E(y_i \mid y_i > 0)$ the conditional intensity of participation. The unconditional mean can be specified below as:

$$\begin{aligned} E(y_i \mid y_i > 0) = {} & X_i^{'}\beta + E(u \mid v > -Z_i^{'}\alpha > -X_i^{'}\beta) \\ & = X_i^{'}\beta + [\varpi(Z_i^{'}\alpha, X_i^{'}\beta/\sigma, \rho]^{-1}\sigma \\ & \times\{\phi(X_i^{'}\beta/\sigma)\Phi[(Z_i^{'}\alpha - \rho X_i^{'}\beta/\sigma)/(\sqrt{1-\rho^2})] \\ & + \rho\phi(Z_i^{'}\alpha)\Phi[(X_i^{'}\beta/\sigma - \rho Z_i^{'}\alpha)/(\sqrt{1-\rho^2})]\} \end{aligned} \tag{3.16}$$

Since the dependent variables were natural log transformed for positive labor time, the conditional elasticities was computed as $(\partial E(y \mid y > 0)/\partial x) * \bar{x}$ and unconditional elasticities was computed as $(\partial E(y)/\partial x) * \bar{x}$ for continuous variables and for discrete variables $\Delta E(y \mid y > 0)$ and $\delta E(y)$. The elasticity for the probability of participation was computed as $\partial p(y_i > 0)/\partial x * (\bar{x}/\bar{P})$ for continuous variables. Marginal effects and elasticities for all variables were evaluated at the mean.

The issue of exclusion restriction for model identification is not very clear in empirical research. Whereas the Type 2 Tobit stipulated exclusion restriction for model identification, the double hurdle model of Cragg’s (1971) did not give any guidance on variables that should be included in both equations. Ghadim et al., (1999) and Jones (1992) recommended exclusion restriction but unfortunately, where the exclusion restriction might come from or which variables to include or exclude is often unclear in empirical application. Owing to this inconclusiveness, Pudney (1989) suggested the inclusion of psychological variables in the participation equation and economic covariates in the intensity equation. His suggestions emanate from the discrete random preference theory whose underlying assumption purports that sample selection is influenced solely by social rather than economic factors. Previous studies contended that there is no standard practice as per the inclusion of variables in the hurdle model. Owing to the foregoing arguments, socio-economic and demographic variables posited to influence both participation and intensity decisions are included in the model.

Proxy reporting and recall biases have been raised in time allocation studies. Palacious-Lopez et al., (2015) indicated that although the issue of proxy reporting bias is not conclusive, differences in self-versus proxy reporting may lead to proxy measurement effects. The authors further stated that male respondents may systematically over report their labor contribution and underreport the labor contribution of women, and vice versa which may bias labor supply estimates. In Tanzania, Bardasi et al., (2011) however found that response by proxy rather than self-report did not bias female labor statistics. Blair et al., (2011) suggested that when people jointly perform an activity or are closer to those who perform such activities, they are likely to provide a realistic account of what the people they are closer to do. The authors further iterated that when people are frequently involved in an activity, it creates a more elaborate memory trace for the information, resulting in enhanced recall. Thus the issue of recall bias may not be severe if at all when people are frequently involved in an activity.

Juster and Stafford, (1991) proposed the use of proportions instead of actual hours if there is recall bias, stating that proportions would cancel out errors in both the numerator and denominator if recall biased is induced. The study proceeded with preliminary checks to investigate potential bias by aggregating individual-disaggregated data on labor input for various activities. The data was then plotted and checked for outliers. The visual scattered plot of individual labor input showed no noticeable outliers. Consequently, we used the continuous distribution of the individual labor input. Moreover, since heads of households are frequently involved in avocado production activities and much familiar with the activities of household members, the issue of proxy and recall bias was not a problem in our data.

Definition and measurement of variables

Variable definitions, measurement and theoretical expectations about their relationship with participation and intensity decisions based on reviewed literature are discussed below.

Dependent Variable

In objective one, the dependent variable for participation decision is coded as a dummy, one for participation and zero otherwise. For objective two, the dependent variables for the intensity of time spent in each activity are continuous captured as time allocated to avocado production, other farming activities, wage employment and non-farm self-employment. For objective three, the dependent variables are continuous variables capturing time allocated to avocado farming activities (land preparation, weeding, harvesting and marketing).

Labor for avocado and other crop farming activities (maize, beans, banana, mango, tea, coffee, cassava, and other livestock production) are defined as time allocated to land preparation, weeding and pest control, harvesting, threshing/winnowing and marketing. Wage labor is defined as skilled or unskilled labor time allocated to agricultural and non-agricultural activities while non-farm self-employment labor is defined as labor allocated to physical, management and marketing/sales activities that do not generate wage or salary earnings.

Independent Variables

Age and Age squared are continuous variables used as proxy for experience and to capture life cycle behavior changes. It is assumed that individuals gain experience as they age which in turn increases the marginal value of time in activities they engage in. The probability of working at youthful age, is expected to increase while the overall labor hours is likely to gradually diminish as individuals get older and the demand for leisure increases. A parabolic relationship is therefore expected between age labor time and the level of time allocated not to each activity (Ilahi, 2001; Fafchamps and Quisumbing 2003)

Education is a continuous variable used as a proxy for human capital. According to human capital theory, education increases an individual's potential and productivity in all tasks thereby providing them with opportunities and options to make independent work decision with more marginal values (Becker, 1965). The education variable was included not only to capture the scope of income generating opportunities available to females and males but also to assess differences in educational endowment and how it alters gender work composition within the household. It is posited that education will reduce participation and level of time in avocado and other farming activities while on the other hand increase participation and its intensity in wage employment and non-farm self-employment (Fafchamps and Quisumbing 2003; Ilahi, 2001) .

*Marital Status i*s a dummy variable, one capturing married and zero widowed, divorced and never married. Marriage may provide more family labor and thus release some for avocado production and other crop farming. It is therefore expected that married persons supply more labor to avocado production and other farm activities, than their unmeasured counterparts. Most often never married persons have the tendency to migrate in search of off-farm activities hence an expected negative relationship (Ilahi, 2001).

Gender of household head is a dummy variable that takes a value one if the head of the household is a male and zero if female. It is used as a proxy indicator to capture gender roles in household decision making on labor resource allocation (assuming that decision on household resource allocation is made by the head) (Ilahi, 2001). It is posited that male-headed households are more likely to have access to opportunities than female-headed households; hence participation decision and intensity are expected to be higher in avocado production and other farming activities for female headed households while a positive probability of working in wage and non-farm self-employment is expected for male headed households (Sikei and Nyangena, 2012)

Age of the household head was included to control for alterations of household labor decisions and intensity due to life cycle effect of the head (Ilahi, 2001; Fafchamps and Quisumbing, 2003). As heads of households get older, their physical capacity for arduous labor declines hence decreasing the likelihood of their engagement in farming and other activities.

Education of the head is a continuous variable used as a proxy for the heads' ability to acquire information and effectively use it to improve the allocative efficiency of household labor resource between agricultural and non-agricultural activities (Yang and An, 2002; Sikei et al., 2009). With significant research indicating positive correlation between education and higher returns from off-farm activities, we form an a priori hypothesis that households heads who are educated have a better chance of engaging in off-farm activities which could in turn positively influence participation and intensity of time use decisions in wage employment and non-farm self-employment. It is however expected to have a negative relationship with avocado production and other farming activities.

*Main occupation of the head i*s a dummy equal to one if the main occupation of the head is farming (farming crop, farming livestock, casual laborer on-farm, herding) and zero otherwise. The occupational status of the head may greatly influence the pattern and behavior of household members' labor decisions (Ilahi, 2001). We expect increased participation and level of participation of both genders in avocado and other farming activities if the head's main occupation is farming and the converse if otherwise.

Number of children in different demographic age groups is the absolute numbers of children between ages 0 to 5 and 6 to14 years. The variable was included to examine the potential role of children in household labor allocation strategy. The presence of children aged five and below in the household is hypothesized to reduce participation and the level of labor time use by females to all activities since care mostly fall in the domain of women (Palacios-Lopez and Lopez, 2015). On the other hand, their male counterparts are expected to allocate more time to income generating activities since the presence of young children requires more income. The presence of older children between the age of 6 to 14 years is expected to increase adult male and female labor to all activities since older children in most rural settings take care of their younger siblings (Fafchamps and Quisumbing 2003; Schindler 2008).

Land ownership: Land measured in acres is the main input in avocado and other agricultural production activities. Households with more land holdings more often engage family labor to specialize in family agriculture thus an increase in acreage will translate into fewer hours in off-farm engagement (Schindler 2008; Sikei and Nyangena (2012). A priori, we expect that an increase in agricultural activities depicted by increase in land size will decrease the probability of participation and intensity of time use in wage and non-farm self-employment for both genders with the converse true for avocado production and other farming activities.

Asset: Household asset is a continuous variable representing the monetary value of all household's asset endowment measured in Kenyan Shillings. These assets are vital for both farming and non-farming activities. Households with more assets that are relevant for farming have higher probability of participating in avocado and other farming activities while those with assets which are important for non-farm activities will allocate the assets and thus their labor time to non-farm activities (Lerman et al., 2004). Hence we cannot a priori determine the direction of the effect of assets on labor supply of adults in the household.

Non labor income includes remittance and rental income. These sources of income relaxes household's cash and credit constraints and provides them with better capacity to diversify their labor time in various profit maximizing activities. On the other hand, this type of income reduces household working hours and increases time to leisure (Beyene, 2008). The variable was measured as a dummy that takes the value one if a household received either or both incomes and zero otherwise. We however draw expectation from Babatunde (2015) who found non-labor income to be positively related to farm and non-farm self-employment with lower effect on wage employment.

Livestock owned is the total number of animals owned by the household expressed in tropical livestock units (TLU). Livestock serves as a buffer stock to smoothen household consumption. In most rural settings, poultry, diary management and care of animals housed within the homestead are mainly done by females (Tangka et al., 2000; Tung, 2005).We therefore expect a negative effect of TLU on female participation and time use in avocado production, wage employment and non-farm self-employment.

Credit constraint is a dummy which equals one if the household is credit constrained and zero if not. It was included as a proxy to isolate the effect of institutional functionality on household labor allocation decisions. A household is classified as credit constrained if it needed credit but could not get (because they had no collateral, no lenders, no knowledge of how to get it, too much paperwork, they were refused credit or got less than what they asked for). Credit constraints prevent households from borrowing to finance agriculture and other investment activities as well as household consumption thus if households are faced with liquidity constraints, they may smoothen this effect by either allocating labor to non-farm activities leading to the withdrawal of agricultural labor (Rao and Qaim, 2011), or may allocate more time to farming activities to generate income for future diversification in non-farm activities. Hence, we cannot make an a priori determination of the sign of the coefficient for both participation and intensity decisions by genders in farming and non-farming activities.

Avocado farmer group membership is a proxy for social capital, measured as a dummy which that takes the value of one if the household member belongs to an avocado farmer group or else zero. Farmer groups usually serve as a support system, medium of information dissemination on crop production, marketing and other opportunities within the community (Oduol et al., 2014; Gyau et al., 2016). We therefore expected a positive correlation between farmer group membership and labor allocation decision and its intensity to avocado and other farming activities while an inverse relationship was expected for wage and non-farm self-employment.

Frequency of avocado group meeting attendance is a continuous variable captured as the number of meetings a famer attended within a year. Attending group meetings regularly and participation in a discussion has a positive effect on farm practices due to both the specified tasks and the learning from group interaction (Fischer and Qaim, 2012).

Voted for officials in avocado farmer's group is a dummy which equal one if the farmer voted for elected officials in the group and zero if they did not. Getting involved in collective decisions and voting for leaders with a vision for the growth of avocados has an important effect on off farm practices and avocado tasks performance ((Fischer and Qaim, 2012).

Received training in avocado agronomy and GAP certification is a dummy coded as one if the farmer received training or else zero. Enhancing human capital through training is expected to improve the efficiency of labor allocation to various tasks in avocado production (Fischer and Qaim, 2012)

Distance to market, measured in kilometers, was used as a proxy for community characteristics and an indication of the proximity to economic activities; consequently, we expect that the longer distance from the market isolates households and reduce their chance of engaging in wage and non-farm self-employment activities thus increasing the probability of participation and more labor time in agricultural related activities by both genders (Sikei et al., 2009).

3.3.3 Data and descriptive statistics

This essay used household data collected by the Productive Employment in Segment Markets of Fresh Produce (PRESM) project collected between November-December 2015 in Murang'a County of Kenya comprised the total number of adults in the sample of 1,109 females and 1,086 males from 790 avocado households. Tables 3.1-3.4 present descriptive statistics of variables used in the analysis. Table 3.1 presents mean comparison test results of dependent variables of labor time allocated by men and women to avocado production activities. The sample comprised of 2,195 adults out of which 1.109 were females and 1,086 males. The adults in our sample spent a relatively greater share of their labor time, equivalent to 47.6 percent, on other farming activities. This is an aggregation of time spent on other crops produced. Of the remaining labor time, about 18.5 percent was spent on wage employment, 17.0 percent on avocado production, and 16.8 percent on non-farm self-employment. The level of time spent by men and women in avocado production, other farming activities, non-farm self-employment and wage employment were similar on average.

The descriptive analysis also shows the gender division of work in avocado production. There was, however, a significant difference between the two groups in labor allocated to marketing of avocados. Men, on average, spent more labor days in marketing activities than their female counterparts.

Table 3.1: Mean Comparison Tests Results of Labor Time Allocation Behavior

Dependent Variables	Females N= 1,109		Males N= 1,086		All Adults N=2,195		
	Mean	SD	Mean	SD	Mean	SD	Difference
Avocado Production	0.1703	0.199	0.1700	0.196	0.1702	0.197	0.003
Other Crop farming	0.4794	0.354	0.4720	0.355	0.4757	0.355	0.0074
Wage Employment	0.1838	0.330	0.1869	0.330	0.1853	0.330	-0.0031
Non-farm Self-Employment	0.1665	0.331	0.1711	0.334	0.1688	0.332	-0.1711
Gender division of work in Avocado production activities							
Land Preparation	12.2046	15.373	11.5844	13.935	11.8981	14.676	0.6202
Weeding	8.4928	11.534	7.5886	10.969	8.0459	11.261	0.9042
Harvesting	15.5402	22.230	16.4010	25.369	15.9666	23.828	-0.8608
Marketing	4.2636	7.982	5.1730	10.855	4.7122	9.517	-0.9094**

**, Significant at 5%

Table 3.2 presents mean values of individual characteristics across females and males and statistics on the significance of the difference in means. The table reveals that significant difference exists in level of educational attainment and main occupation. Men had more years of education than females while more females had farming as their main occupation compared to males. The proportion of males that received training was three times larger than females. About 34 percent of adults participated in avocado contract farming, but the test statistics showed females and males were not different in terms of participation. More males than females voted for leaders elected in avocado groups. The two groups were not different in terms of age, credit constraint, non-labor income received and the number of avocado meeting attended within 12 months.

Table 3.2: Mean Comparison Tests Results of Individual Characteristics

Independent Variables	Females N= 1,109		Males N= 1,086		All Adults N=2,196		
	Mean	SD	Mean	SD	Mean	SD	Difference
Age of adults (years)	47.892	19.584	47.724	20.990	47.809	20.288	0.168
Educational attainment (years)	7.986	3.798	9.273	3.474	8.623	3.697	-1.287***
Main Occupation (Farming=1; 0otherwise)	0.734	0.442	0.642	0.480	0.689	0.463	0.092***
Marital status (married=1)	0.537	0.499	0.567	0.496	0.551	0.497	-0.030
Credit constrained (yes=1)	0.197	0.398	0.182	0.386	0.189	0.392	0.015
Participated in contract farming (yes=1)	0.341	0.474	0.331	0.471	0.336	0.472	0.010
Non-labor income (yes=1)	0.297	0.457	0.275	0.447	0.286	0.452	0.022
Received training (yes=1)	0.203	0.411	0.654	0.405	0.427	0.408	-0.451***
Number of avocado meeting attended in 12 months	8.012	7.557	9.100	0.363	8.553	8.103	-1.088
Voted for leaders in avocado group meeting (yes=1)	0.460	0.481	0.613	0.474	0.537	0.477	-0.153***

***, Significant at 1%

Mean comparison test results of household head characteristics in Table 3.3 indicate that females and male heads were significantly different in the level of educational attainment and main occupation. Male household heads on average attained more education than female heads. The implication of this is that households headed by males who are well educated may have access to information on opportunities which places them in better position of diversifying their labor time. On the other hand, more female heads (81 percent compared to 78 percent males) had farming as their main occupation. The difference between the two heads in terms of age was not statistically significant.

Table 3.3: Comparison Tests Results of Household Head Characteristics

Independent Variable	Female heads N= 166		Male heads N = 624		All heads N=790		
	Mean	SD	Mean	SD	Mean	SD	Difference
Age (years)	61.350	13.338	60.725	13.293	61.036	13.317	-0.625
Educational attainment (years)	8.260	3.834	8.648	3.594	8.455	3.720	-0.388***
Main occupation (Farming=1; 0 otherwise)	0.819	0.385	0.786	0.410	0.802	0.398	0.033**

,*, Significant at 5% and1%

Table 3.4 presents descriptive statistics of household characteristics. The table shows that households with children aged between zero to five and six to fourteen years represent 13 and 61 percent of the sample respectively. The mean value of both agricultural and non-agricultural assets was Ksh39, 945 and households on average owned 2 acres of land. About 35 percent of households owned livestock and covered about 3.7 kilometers distance to the market.

Table 3.4: Descriptive Statistics of Household Characteristics

Variables	Mean	SD	Min	Max
Number of children (0-5)	0.129	0.389	0	3
Number of children (6-14)	0.614	0.949	0	5
Value of assets (Ksh)	39,945.130	113831.6	700	1,469,570
Total land owned (acres)	2.097	1.927	0	20
Owned livestock size (TLU)	0.355	0.374	0	3.5
Distance to market (km)	3.710	9.261	0	75

3.4 Empirical results and discussion

3.4.1 Section overview

This section presents empirical results of factors influencing gender patterns in labor allocation to avocado production and other economic activities as well as the level of time to each activity. The section is divided into three sub-sections. The first subsection 3.4.2 presents regression results from the first tier (participation) while the second subsection 3.4.3 presents results from the second tier (intensity of participation) that answers objective one and two. The third sub section

3.4.4 presents regression results for objective three the role of avocado contract farming on gender labor allocation.

3.4.2 Regression results for factors influencing participation decision by gender

In order to identify the best model fit for our study, nested and non-nested selection criterions were used. The likelihood result indicating that Tobit model is nested within the double hurdle model for each activity is presented in Table A5. Secondly, the appropriateness of the double hurdle model is validated by the significant correlation coefficient between unobservable factors of the first hurdle (participation decision) and the second hurdle (intensity of participation) for all activities measured by sigma which suggest a robust dependence between the two tiers. The correlation coefficients attained from the joint maximum likelihood estimates of participation and intensity decisions of the DHM are presented in Tables A7 and A8. Consequently, we focus our analysis on regression results from the first tier of the double hurdle model in Table 3.5.

The age participation profile revealed only marginal significance on female avocado labor supply. An additional year of education had no effect on female labor supply but was positively correlated with male labor supply to avocado production. Unexpectedly, more years of education increased the likelihood of more male participation in avocado production compared to wage employment. This result could perhaps be attributed to the expected benefit from producing avocado, which has increasing national and global demand and provides higher payoff for education than wage employment. Sikei et al., (2009) concluded that household reallocation of labor from non-farm self-employment to agricultural activities was a response to the returns from such activities. It was less possible for older household heads to supply labor to avocado production while males were more likely than females to participate in avocado production when the occupation of the household head was farming.

The results also indicated that females of all ages supplied less labor in wage employment while males participated less at a younger age, but their participation increased gradually as they grew older. On the other hand it was more possible for females to participate in non-farm self-employment than males as they grew older. The chances of participation in wage employment by households headed by males increased by 8.6 percentage points for females and 10.4 percentage points for males. Aging of the household head reduced female labor supply in wage employment but increased their participation in non-farm self-employment. In contrast, the age of the household head did not significantly influence male labor supply. Educational attainment of the household head was positive and significantly related to female labor supply in other crop production activities but had a negative effect on wage employment. This effect was only marginally significant for males in non-farm self-employment.

Household heads that practiced farming as the main occupation had a higher probability of participation in other crop farming with less labor supply going to wage and non-farm self-employment by both groups. Results also revealed that females from households with young children aged five years and below, unlike their male counterparts, were less likely to supply labor to wage employment. Both groups supplied more labor to non-farm self-employment but the probability increased by 3.4 percentage points for males from households with young children. The overall findings indicated that individual characteristics and household composition affected male and female labor decisions in different ways. Our finding is consistent with other related studies (Fafchamps and Quisumbing 2003; Ilahi, 2000; Schindler, 2008).

The effect on household assets and financial endowment on participation showed similar patterns in both groups. However, although both male and female labor supply in avocado production increased with asset level and non-farm income, the chances of male participation were 1.1 percentage points higher than female participation under the similar conditions. On the other hand, the chances of participation by females were 0.4 percentage points higher relative to male participation with increase in non-labor income. Similarly, the probability of female engaging in non-farm self-employment was 0.02 times higher than that of male participation. The chances of supplying less labor with increase in non-farm income were 0.06 times higher for males than females.

Non-labor income lowered the probability of participation in wage employment by 18.8 percentage points in males and 19.7 percentage points in females. Total livestock units owned had a positive correlation with male participation in other crop farming but this association was not significant for female farmers. Furthermore, the probability of male participation in other crop production when facing credit constraints was 5.9 percentage points higher than for female participation under similar circumstances. There was a positive correlation between credit constraints and female involvement in non-farm self-employment but the effect was not significant for males. This could be explained by the fact that credit constrained women opt to look for non-farm employment for a livelihood. Unlike their male counterparts, females were likely to spend more time in avocado production with increase in non-labor income and less time when facing credit constraints. This could probably mean that non-labor income relaxes credit constraints that women farmers face and thus enable them to spend more time in avocado production. Credit constraints may however induce them to search for other non-farm opportunities thereby reducing time spent in avocado production. The overall results imply that gender based heterogeneities in economic assets and opportunities influence gender differentials in labor allocation decisions which also reinforce differences in opportunities (Ilahi, 2000).

Group membership had varying effect on participation incentives for both groups, but distance to the market reduced the chances of female participation in wage employment without seeming to affect male participation. The overall findings show that household asset ownership, credit constraints, group membership, and distance to market were significant correlates explaining gender patterns in avocado production and other activities.

Table 3.5: Average Partial Effects of Double Hurdle Model for Determinants of Participation

	Probit marginal Effect of Participation							
Variable	Avocado Production		Other Crop Production		Wage Employment		Non-Farm Self-Employment	
Household characteristics	Female	Male	Female	Male	Female	Male	Female	Male
Age of adults(years)	0.0067*	0.0031	0.0032	-0.0021	-0.0079**	-0.0146***	-0.0116***	-0.0058*
	(0.0036)	(0.0038)	(0.0023)	(0.0025)	(0.0035)	(0.0038)	(0.0032)	(0.0032)
Age squared	-0.1128*	-0.0494	-0.0460	0.0479	0.0913	0.2420***	0.1931***	0.1033
	(0.0685)	(0.0746)	(0.0452)	(0.0488)	(0.0657)	(0.0734)	(0.0611)	(0.0632)
Education of adults (years)	0.0034	0.0113**	-0.0013	0.0041	-0.0052	-0.0118**	-0.0006	-0.0057
	(0.0051)	(0.0056)	(0.0033)	(0.0037)	(0.0048)	(0.0053)	(0.0044)	(0.0050)
Gender of head dummy (male=1)	-0.0269	-0.0302	-0.0644**	-0.0525	0.0864***	0.1035**	0.0185	-0.0797**
	(0.0367)	(0.0486)	(0.0257)	(0.0359)	(0.0332)	(0.0456)	(0.0314)	(0.0386)
Age of household head (years)	-0.0032**	-0.0039***	-0.0014	-0.0015	-0.0035***	-0.0007	0.0027**	-0.0003
	(0.0014)	(0.0015)	(0.0009)	(0.0011)	(0.0013)	(0.0014)	(0.0011)	(0.0012)
Education of household head (years)	0.0052	-0.0068	0.0085***	-0.0005	-0.0118***	-0.0049	-0.0065*	0.0067
	(0.0045)	(0.0053)	(0.0027)	(0.0033)	(0.0041)	(0.0050)	(0.0038)	(0.0047)
Occupation of Household head (1=farming; 0 otherwise)	0.1773***	0.1888***	0.1000***	0.1043***	-0.0694**	-0.1076***	-0.2125***	-0.1826***
	(0.0373)	(0.0354)	(0.0234)	(0.0223)	(0.0326)	(0.0336)	(0.0291)	(0.0292)
Number of children (0-5) years	-0.0237	-0.0600*	0.0253	0.0025	-0.0623**	-0.0254	0.0881***	0.1216***
	(0.0343)	(0.0355)	(0.0233)	(0.0235)	(0.0307)	(0.0343)	(0.0264)	(0.0296)
Number of children (6-14) years	-0.0054	-0.0124	-0.0098	-0.0076	0.0094	-0.0068	0.0124	0.0039
	(0.0149)	(0.0148)	(0.0095)	(0.0104)	(0.0133)	(0.0144)	(0.0122)	(0.0129)
Physical and financial assets								
Ln total assets (KSh)	0.0456***	0.0565***	-0.0133	-0.0032	-0.0164	-0.0137	0.0362***	0.0222**
	(0.0140)	(0.0133)	(0.0086)	(0.0082)	(0.0123)	(0.0124)	(0.0114)	(0.0109)
Non-labor income (yes=1)	0.0918***	0.0882***	0.0193	0.0097	-0.1966***	-0.1879***	-0.1016***	-0.1641***
	(0.0318)	(0.0331)	(0.0205)	(0.0216)	(0.0304)	(0.0331)	(0.0281)	(0.0317)
Total land owned (acre)	-0.0062	0.0015	-0.0054	0.0008	-0.0151	-0.0041	0.0072	0.0043
	(0.0077)	(0.0091)	(0.0041)	(0.0060)	(0.0092)	(0.0080)	(0.0055)	(0.0062)

Owned livestock size (TLU)	0.0232	-0.0088	0.0269	0.0495**	-0.0383	-0.0555	-0.0077	-0.0039
	(0.0399)	(0.0386)	(0.0219)	(0.0241)	(0.0406)	(0.0445)	(0.0349)	(0.0350)
Credit constrained (yes=1)	-0.0351	-0.0412	0.0942***	0.1529***	0.0277	0.0351	0.0613**	0.0112
	(0.0341)	(0.0349)	(0.0280)	(0.0360)	(0.0300)	(0.0329)	(0.0289)	(0.0318)
Social Capital and Community variable								
Group membership (yes=1)	0.0476	0.0638*	0.0363*	0.0448**	0.0705**	0.0613*	0.0268	-0.0078
	(0.0336)	(0.0336)	(0.0210)	(0.0208)	(0.0327)	(0.0344)	(0.0311)	(0.0313)
Distance to market (km)	0.0049***	0.0039**	0.0034***	0.0029***	-0.0046***	-0.0015	0.0005	-0.0001
	(0.0016)	(0.0016)	(0.0011)	(0.0011)	(0.0019)	(0.0015)	(0.0013)	(0.0013)
Constant	0.5516	-0.4797	2.9072*	-0.3891	0.1892	-3.0870**	-5.4384***	-2.4991
	(1.1582)	(1.3450)	(1.5597)	(1.8190)	(1.2923)	(1.4439)	(1.3119)	(1.4039)
Wald chic2(16)	71.02	53.41	140.3	147.39	68.91	83.84	46.71	49.15
Prob>chi2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
Log pseudolikelihood	-158.948	-140.654	-161.147	-157.665	-449.893	-482.742	-439.248	-442.837
Observations	1,109	1,086	1,109	1,086	1,086	1,109	1,109	1,086

Robust standard errors in parenthesis, *, **, *** Significant at 10%, 5% and 1%

3.4.3 Regression results for factors influencing the intensity of time use by gender

Regression results discussed from the conditional and unconditional average partial effect from both hurdles are presented in Tables 3.6 and 3.7. The age and age squared data capturing the life circle effect from both conditional and unconditional elasticities shows that male time allocation to other crop production activities increases but at a decreasing rate while, on average, the effect is linear for females. Conditional on participation, age has a U-shaped effect on female time use in non-farm self-employment but no significant effect for male participants. The unconditional effect shows that, on average, the propensity of time use by females in wage employment and by males in non-farm self-employment increases with age. The unconditional elasticity indicates that, on average, educated males tend to work more on other farm activities. This unexpected finding diverges from returns to education theory (Fafchamps and Quisumbing 2003). Our finding however corroborates those of Sikei & Nyangena (2012) who found positive correlation between returns to farming and time. On the contrary, Ilahi (2001) found no significant relationship between education and adult time use.

Both the conditional and unconditional partial effects indicate that females from male- headed households were likely to spend less time in avocado production. On the other hand, male time did not seem to be significantly affected. Similarly, the unconditional effect shows a positive association of male headship and female time use in wage employment and negative relationship in non-farm self-employment for males. The substitution effect of female time use could probably be that in male-headed households, the availability of male labor affords female members the opportunity to allocate time to wage employment. Age of the head of household seemed to lower the unconditional chance of time use in wage employment by the household head and female members but increase time use in non-farm self-employment.

Table 3.6: Average Partial Effects of Parameter Estimates of DHM for Intensity of Female and Male Labor Allocation

Variable	Conditional Intensity of Labor Time Use							
	Avocado Production		Other Farming Activities		Wage Employment		Non-Farm Self-Employment	
Household characteristics	Female	Male	Female	Male	Female	Male	Female	Male
Age of adults (years)	-0.0001	0.0017	0.0031*	0.0081***	0.0050**	-0.0010	0.0038	0.0016
	(0.0013)	(0.0015)	(0.0016)	(0.0020)	(0.0024)	(0.0029)	(0.0027)	(0.0035)
Age squared	-0.0115	-0.0311	-0.0413	-0.1546***	-0.0821*	0.0277	-0.0379	-0.0122
	(0.0251)	(0.0288)	(0.0326)	(0.0394)	(0.0459)	(0.0603)	(0.0515)	(0.0658)
Education of adult male/female (years)	-0.0024	-0.0018	0.0006	0.0063	0.0012	-0.0039	0.0051	0.0006
	(0.0019)	(0.0023)	(0.0026)	(0.0031)	(0.0035)	(0.0039)	(0.0038)	(0.0044)
Gender of head dummy (male=1)	-0.0299**	0.0077	-0.0121	0.0219	-0.0303	-0.0153	-0.0333	-0.0792**
	(0.0132)	(0.0177)	(0.0176)	(0.0262)	(0.0256)	(0.0337)	(0.0275)	(0.0336)
Age of household head (years)	0.0008	-0.0001	0.0001	-0.0001	0.0005	0.0025*	0.0010	0.0002
	(0.0006)	(0.0006)	(0.0007)	(0.0008)	(0.0009)	(0.0013)	(0.0010)	(0.0012)
Education of household head (years)	0.0029	0.0024	0.0064***	-0.0013	-0.0046	-0.0015	-0.0012	0.0029
	(0.0018)	(0.0020)	(0.0023)	(0.0028)	(0.0029)	(0.0047)	(0.0032)	(0.0039)
Occupation of Household head (Farming=1; 0 otherwise)	0.0460***	0.0604***	0.1345***	0.1149	-0.0186	-0.0072	-0.0522**	-0.0389
	(0.0179)	(0.0170)	(0.0274)	(0.0266)	(0.0293)	(0.0258)	(0.0244)	(0.0251)
Proportion of children (0-5) years	-0.0513***	-0.0355**	-0.0192	-0.0483***	0.0011	-0.0202	0.0152	0.0121
	(0.0166)	(0.0164)	(0.0196)	(0.0245)	(0.0284)	(0.0339)	(0.0184)	(0.0187)
Proportion of children (6-14) years	-0.0110*	-0.0117*	-0.0125	-0.0032	0.0280***	0.0398***	0.0042	0.0050
	(0.0060)	(0.0066)	(0.0085)	(0.0084)	(0.0086)	(0.0098)	(0.0134)	(0.0145)
Physical and financial assets								
Ln total assets (Ksh)	0.0091*	0.0045	-0.0054	-0.0025	-0.0339***	-0.0191**	0.0004	-0.0091
	(0.0052)	(0.0052)	(0.0068)	(0.0068)	(0.0102)	(0.0091)	(0.0105)	(0.0114)
Non-labor income (yes=1)	0.0022	-0.0068	0.0944***	0.1024***	-0.0495*	-0.0980***	0.0269	0.0076
	(0.0115)	(0.0120)	(0.0136)	(0.0140)	(0.0265)	(0.0296)	(0.0258)	(0.0330)
Total land owned (acre)	0.0059**	0.0079***	0.0019	-0.0033	0.0040	-0.0074	-0.0056	-0.0053
	(0.0027)	(0.0028)	(0.0040)	(0.0040)	(0.0053)	(0.0108)	(0.0049)	(0.0066)

Owned livestock size (TLU)	-0.0546**	-0.0600***	-0.0070	0.0075	0.0397	0.0399	0.0636*	0.0518
	(0.0212)	(0.0214)	(0.0212)	(0.0206)	(0.0373)	(0.0319)	(0.0331)	(0.0353)
Credit constrained (yes=1)	-0.0457***	-0.0169	-0.0182	-0.0182	-0.0325	-0.0006	-0.0027	-0.0255
	(0.0136)	(0.0136)	(0.0179)	(0.0190)	(0.0265)	(0.0265)	(0.0253)	(0.0308)
Social Capital and Community Characteristics								
Group membership (yes=1)	0.0019**	0.0077**	-0.0216	-0.0015	-0.0626**	-0.0955***	-0.1134***	-0.1281***
	(0.0120)	(0.0125)	(0.0165)	(0.0175)	(0.0273)	(0.0247)	(0.0228)	(0.0212)
Distance to market (km)	0.0002	-0.0004	0.0002	-0.0009	0.0024*	0.0036**	-0.0022	0.0001
	(0.0005)	(0.0005)	(0.0006)	(0.0007)	(0.0013)	(0.0008)	(0.0021)	(0.0018)
Constant	0.0091	0.2727	0.4121	1.2466***	1.2554***	0.4421	0.6815**	0.7714**
	(0.3141)	(0.3561)	(0.2659)	(0.3473)	(0.2598)	(0.3739)	(0.3056)	(0.3915)
Wald chic2(16)	71.02	53.41	140.30	147.39	68.91	83.84	46.71	49.15
Prob>chi2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
Log pseudolikelihood	-158.948	-140.654	-161.147	-157.665	-449.893	-482.742	-439.248	-442.837
lnsigma	-1.5779***	-1.5931***	-1.3747***	-1.3367***	-1.7653***	-1.7165***	-1.7669***	-1.7169***
	(0.0520)	(0.0524)	(0.0287)	(0.0298)	(0.0421)	(0.0453)	(0.0453)	(0.0431)
Sigma	0.2064	0.2033	0.2529	0.2627	0.1711	0.1797	0.1709	0.1796
	(0.0107)	(0.0107)	(0.0073)	(0.0078)	(0.0072)	(0.0081)	(0.0077)	(0.0077)
Observations	1,109	1,086	1,109	1,086	1,086	1,109	1,109	1,086

Robust standard errors in parenthesis, *, **, *** Significant at 10%, 5% and 1%

The unconditional elasticity shows that, on average, household heads and female members were more likely to allocate time to avocado and other crop production and less likely to wage employment when the household head attains an additional year of education. Also, both males and females tended to spend more of their time in avocado production and other crop farming activities, but less in wage and non-farm self-employment when the principal occupation of the head of household was farming. The conditional probability shows that in households with young children aged five years and below, there was a high probability that both male and females would spend less time, of varying magnitude, in avocado production. In this case, time allocation was found to reduce by an average of 5.1 and 3.6 percentage points for females and males respectively. Similarly, with the presence of older children aged 6 to 14 years, both groups were likely to increase their time share in wage employment by different magnitudes. The overall findings imply that composition of the household shapes time behavior in different ways for males and females, which is in line with Schindler's (2008) who found varying effects on adult time use.

Unconditional mean revealed a high probability that use of time in avocado production by females and males would increase by 2 percentage points and 1 percentage point respectively with increase in assets. Unlike their male counterparts, females were likely to spend more time in avocado production with increase in non-labor income and less time when facing credit constraints. Moreover, conditional on participation in avocado production, land ownership increased the chances of time use by males by 8 percentage points while the chances of increase due to group membership were 7 percentage points. In females, land ownership and group membership increased time use by 6 and 2 percentage points respectively. On the other hand, livestock units owned lowered time use for males by 6 percentage points and for females by 5.4 percentage points.

Males and females also exhibited different patterns of time allocation to other activities. The unconditional elasticity showed that, on average, asset ownership reduced time use by females in wage employment, but this effect was marginal for males. Females were also found to increase their time share in non-farm self-employment while male time use for this activity was not different from zero.

Table 3.7: Average Partial Effects of Parameter Estimates of DHM for Intensity of Female and Male Labor Allocation

Variable	Unconditional Marginal Effect							
	Avocado Production		Other Farming Activities		Wage Employment		Non-Farm Self-Employment	
Household characteristics	Female	Male	Female	Male	Female	Male	Female	Male
Age of adults (years)	0.0013	0.0018	0.0040**	0.0065***	-0.0026	-0.0073***	-0.0052***	-0.0026
	(0.0011)	(0.0013)	(0.0017)	(0.0020)	(0.0019)	(0.0020)	(0.0019)	(0.0018)
Age squared	-0.0307	-0.0312	-0.0544	-0.1205***	0.0228	0.1240***	0.0926***	0.0502
	(0.0219)	(0.0249)	(0.0334)	(0.0403)	(0.0353)	(0.0393)	(0.0354)	(0.0355)
Education of adult male/female (years)	-0.0010	0.0010	0.0001	0.0073**	-0.0023	-0.0068**	0.0008	-0.0028
	(0.0016)	(0.0018)	(0.0026)	(0.0031)	(0.0026)	(0.0028)	(0.0025)	(0.0028)
Gender of head dummy (male=1)	-0.0259**	-0.0008	-0.0349*	-0.0003	0.0345**	0.0453*	0.0021	-0.0597***
	(0.0117)	(0.0154)	(0.0184)	(0.0272)	(0.0176)	(0.0238)	(0.0179)	(0.0212)
Age of household head (years)	-0.0001	-0.0009*	-0.0004	-0.0007	-0.0016**	0.0004	0.0017**	-0.0001
	(0.0005)	(0.0005)	(0.0007)	(0.0008)	(0.0007)	(0.0008)	(0.0007)	(0.0007)
Education of households (years)	0.0031**	0.0003	0.0089***	-0.0013	-0.0071***	-0.0028	-0.0037*	0.0041
	(0.0015)	(0.0016)	(0.0023)	0.0028	(0.0022)	(0.0028)	(0.0022)	(0.0027)
Occupation of Household head	0.0673***	0.0792***	0.1584***	0.1427***	-0.0393**	-0.0537***	-0.1233***	-0.1030***
	(0.0145)	(0.0134)	(0.0262)	(0.0251)	(0.0173)	(0.0177)	(0.0163)	(0.0163)
Proportion of children (0-5) years	-0.0398***	-0.0363***	-0.0079	-0.0424*	-0.0305*	-0.0180	0.0496***	0.0653***
	(0.0133)	(0.0133)	(0.0198)	(0.0244)	(0.0173)	(0.0198)	(0.0138)	(0.0152)
Proportion of children (6-14) years	-0.0086*	-0.0105**	-0.0149*	-0.0057	0.0123*	0.0081	0.0074	0.0032
	(0.0049)	(0.0054)	(0.0085)	(0.0085)	(0.0070)	(0.0075)	(0.0071)	(0.0076)
Physical and financial assets								
ln total assets (Ksh)	0.0154***	0.0144***	-0.0098	-0.0035	-0.0174**	-0.0120*	0.0191***	0.0093
	(0.0043)	(0.0040)	(0.0070)	(0.0069)	(0.0072)	(0.0070)	(0.0068)	(0.0065)
Non-farm income (yes=1)	0.0201**	0.0131	0.0922***	0.0956***	-0.0837***	-0.0622***	-0.0472***	-0.0825***
	(0.0099)	(0.0104)	(0.0145)	(0.0151)	(0.0168)	(0.0179)	(0.0159)	(0.0182)
Total land owned (acre)	0.0028	0.0057**	-0.0003	-0.0027	-0.0063	-0.0041	0.0025	0.0009
	(0.0023)	(0.0026)	(0.0036)	(0.0042)	(0.0054)	(0.0058)	(0.0033)	(0.0039)
Owned livestock size	-0.0326**	-0.0428***	0.0037	0.0255	-0.0081	-0.0152	0.0104	0.0102

	(0.0169)	(0.0167)	(0.0207)	(0.0202)	(0.0222)	(0.0244)	(0.0165)	(0.0161)
Credit Constrained (yes=1)	-0.0383***	-0.0198*	0.0187	0.0417**	0.0048	0.0167	0.0315**	-0.0003
	(0.0118)	(0.0118)	(0.0190)	(0.0214)	(0.0159)	(0.0170)	(0.0160)	(0.0179)
Social Capital								
Group membership (yes=1)	0.0083	0.0075	-0.0059	0.0157	0.0178	0.0022	-0.0118	-0.0343**
	(0.0109)	(0.0111)	(0.0169)	(0.0175)	(0.0178)	(0.0181)	(0.0173)	(0.0172)
Distance to market (km)	0.0012***	0.0005	0.0015**	0.0003	-0.0017	0.0003	-0.0002	0.0000
	(0.0005)	(0.0005)	(0.0007)	(0.0008)	(0.0011)	(0.0008)	(0.0008)	(0.0008)
Constant	0.0091	0.2727	0.4121	1.2466***	1.2554***	0.4421	0.6815**	0.7714**
	(0.3141)	(0.3561)	(0.2659)	(0.3473)	(0.2598)	(0.3739)	(0.3056)	(0.3915)
Wald chic2(16)	71.02	53.41	140.30	147.39	68.91	83.84	46.71	49.15
Prob>chi2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
Log pseudolikelihood	-158.948	-140.654	-161.147	-157.665	-449.893	-482.742	-439.248	-442.837
lnsigma	-1.5779***	-1.5931***	-1.3747***	-1.3367***	-1.7653***	-1.7165***	-1.7669***	-1.7169***
	(0.0520)	(0.0524)	(0.0287)	(0.0298)	(0.0421)	(0.0453)	(0.0453)	(0.0431)
Sigma	0.2064	0.2033	0.2529	0.2627	0.1711	0.1797	0.1709	0.1796
	(0.0107)	(0.0107)	(0.0073)	(0.0078)	(0.0072)	(0.0081)	(0.0077)	(0.0077)
Observations	1,109	1,086	1,109	1,086	1,086	1,109	1,109	1,086

Robust standard errors in parenthesis, *, **, *** Significant at 10%, 5% and 1%

3.4.4 The role of avocado contract farming on gender labor allocation

This sub section presents empirical analysis of the role of contract farming on gender pattern of labor allocation in avocado production. The increase in the demand for avocados has led to increasing household investment in avocado production. The expansion in investment is aligned towards contract farming which may have consequently shifted gendered labor patterns. This analysis was therefore geared at grasping the extent and influence of contract farming on possible changes in gender roles regarding the amount of time spent on specific tasks and identifying factors that constraint or improve participation and time allocation in the various tasks. In order to analyze the role of contract farming on gender labor allocation pattern, the research first presents an overview of gender roles in avocado farming based on discussion with group avocado members during their structured interview.

Avocado farming may be seen as relatively less labor intensive from the outside, farmers however complained that production is not as simple as it appears especially with the quality requirements and hygiene standards now required for Good Agricultural Practice (GAP) certification. The fruit is mainly produced by household members and in some cases with the help of hired labor for household that can afford. Traditional roles consider activities such as planting, grafting, weeding and post-harvest activities like cleaning, sorting, grading and waxing of fruits as women's role since women are more dexterous and the tasks require keenness, patience and takes considerable amount of time. Harvesting which entails tree climbing, land preparation, spraying and pruning were considered men's role since the tasks require muscle strength. The marketing of avocados was mainly done by men because it is believed that women had little or no experienced in negaotiating the terms of sales with brokers who may likely cheat them. In male headed households, wives whose husbands were involved in contract farming also performed hygiene standards tasks such as sweeping the avocado farms, cleaning the toilets as well as watering the trees during the dry seasons. The division of tasks in female headed household is however much different since there are few or no available male labor.

The dependent variables to address this objective are labor time allocated by males and females to avocado production. These activities include land preparation (digging, planting, pruning and grafting) weeding (weeding and pest control), harvesting and marketing. The natural logarithms of positive observation of the dependent variables were taken to adjust the data for non-normality. With reference to gender roles, the effect of contract farming is analyzed by including other controls such as number of *Hass* and *Fuerte* trees owned, marital status, the number of meetings attend during the last twelve months, training attended, and whether they voted for leaders in avocado farmer's group. Unlike previous analysis, gender of the household head and characteristics were not included as separate variables but rather included as household variables for all adults above 15 years. This was due to preliminary analysis which showed that household head characteristics were highly correlated with female and male contract labor.

Analysis began with the likelihood test for nested models. The Tobit model was used for the analysis since the null hypothesis of the Tobit nested in the double hurdle model was not rejected by the likelihood test. The likelihood and F-statistics in Table 3.8 indicate that our model fits the data well. The basic hypothesis is that avocado contract farming has changed traditional women's roles in avocado production activities. Our analysis considered only the unconditional marginal effects since our interest lies in the average effect of positive observations.

From the results in Table 3.8 contract farming increased both male and female participation in avocado farming activities, suggesting that avocado contract farming increased both male and female labor demand. Notable differences were however observed between the two groups in participation and level of time spent in land preparation, weeding and marketing. In particular, the result showed that a 10 percent increment in smallholder participation in avocado contract farming increased male participation and time spent in land preparation by 21 percentage points and females by 2 percentage points. On the other hand, females on average increased participation in weeding and related activities by 47 percentage points and males by 11 percentage points when contract participation increased. The coefficient of male participation in weeding was not statistically significant. The result implies that traditional roles of greater male involvement in activities such as digging and pruning and women involvement in weeding still holds in these activities.

For harvesting of avocados, increase in contract farming improved the prospect of male participation in harvesting by 85 percentage points and females by 15 percentage points. Harvesting of avocados was traditionally a man's activity since it involves tree climbing. The involvement of women in this male dominated activity suggests a possible shift in traditional gender role. Conversely, in marketing, a 10 percent increase in contract farming increased male participation and intensity of time spent by equal amount but reduced female participation by 17 percentage points but coefficient was statistically insignificant. This finding is in line with studies by Fischer and Qaim, (2012) and Oduol et al., (2017) which showed the possible exclusion of women farmers from the export value chain as crops become more commercialized. On the overall, although there seem to be a slight shift, most of the traditional gender roles are still practiced in avocado contract farming. This suggests the need for innovative gender awareness strategy that would ensure women farmers are not disadvantage in production since contract farming increased participation and time use in gender segregated activities.

Age reduced the probability of female participation and time use in avocado production activities but had no significant effect on male participation and time use. The education of males was a factor in increasing the probability of male participation in marketing. Education enhanced the capability and managerial ability of male farmers to utilize market information and involve themselves in complex contract farming transactions. The result is supported by the descriptive analysis in Table 3.2 which showed that males had more years of education than their female counterparts. It also corroborates with finding in Mwambi et al., (2013), who found education to be a significant predictor of contract farming. The implication is that improving the capabilities of female famers could enable them participate in marketing activities as their male counterparts. As expected, farming as the main occupation increased the participation of both groups in avocado production activities.

The result also revealed a significant and negative relationship between marital status for males and avocado harvesting. This is understandable because single young men in the household could easily climb avocado trees and thus are more probable to participate in avocado harvesting than married men. This effect was marginally significant for females in land preparation. As expected, larger household size increased the probability of participation in avocado production activities. The insignificant effect of household size in marketing could probably be that since avocado trees are mostly owned by the head of household, marketing transactions involving sales of avocados are mostly done by them. The presence of children aged five and below reduced the probability of female participation in land preparation, weeding and marketing but increased male participation and time use in harvesting and marketing. But this occurrence for males could possibly be explained by the demand for income to care for the young.

Findings further indicate that as the number of *Hass* trees increases, the chance of male participation in land preparation and females in weeding also increases. In harvesting and marketing, female participation and time use increased by 0.7 and 0.3 percentage points respectively while male participation increased by 32 and 24 percentage points in harvesting and marketing. This means that as more commercial *Hass* trees are grown, women become more involved in roles that traditionally ought to be performed by males. Non-labor income increased the chance of female participation in weeding and marketing and males in marketing. Non-labor income facilitates market transactions for avocado sales and enables women put in more time to their tasks. Conversely, credit constraints reduced the probability of both female and male participation in production and marketing activities. This implies that credit constraint serves as a barrier to avocado production.

The number of avocado meetings a farmer attended was significantly positive for all avocado production activities with the exception of males in weeding and females in marketing. Regular meeting attendance helps farmers to be dedicated to their respective tasks in avocado production. An interesting finding was the positively significant coefficient associated with voting for leaders in avocado group for females in all activities and the insignificant effects for males. This could perhaps be that for female, bringing out their voices through voting for avocado group leadings serves as a motivation for more female participation and time use in avocado production. While for male farmers, they are the ones most often elected and voting for them could not be of much significance to their tasks.

Participation in avocado agronomy and marketing training increased the probability of male participation and time use in land preparation, harvesting and marketing. The effect was however insignificant for females in all activities. The insignificant effect of training on all activities could probably be as indicated by Oduol et al., (2014) that it is mostly male farmers who are members of groups that receive trainings. The assumption that heads of households who receive trainings could transfer the information to other household members may not help women farmers because information may not be related in the proper manner. Including women in trainings mean providing them with equitable access to resources that will enhance the efficiency of their labor.

Table 3.8: Average Partial Effects of Tobit Model for Female and Male Avocado Contract Labor Allocation

	Unconditional expectations							
Variables	Land Preparation		Weeding & pests control		Harvesting		Marketing	
	Female	Male	Female	Male	Female	Male	Female	Male
Contract farming(yes=1)	0.016*	2.054**	0.472**	0.114*	0.150**	0.854**	-0.174	1.058***
	(1.621)	(1.675)	(1.383)	(0.832)	(1.074)	(1.092)	(0.441)	(0.520)
Age of adults (years)	-0.101***	0.014	-0.086**	0.015	-0.105***	-0.001	0.024	-0.015
	(0.036)	(0.054)	(0.036)	(0.025)	(0.037)	(0.036)	(0.016)	(0.017)
Education of adults (years)	-0.061	0.123	-0.006	0.271	0.077	0.226	0.097	0.015**
	(0.185)	(0.185)	(0.177)	(0.109)	(0.176)	(0.153)	(0.071)	(0.068)
Main occupation (Farming=1; 0 otherwise)	3.834***	6.333***	5.353***	1.351*	4.601***	8.170***	0.149	3.052***
	(1.404)	(1.417)	(1.332)	(0.810)	(1.224)	(1.187)	(0.546)	(0.568)
Marital status (Married=1)	2.039*	2.172	1.472	-0.657	-0.264	-2.901**	-0.384	-0.887
	(1.138)	(2.384)	(1.005)	(1.025)	(0.976)	(1.384)	(0.398)	(0.652)
Household size (no. of persons)	0.831***	1.175***	0.775**	0.439**	0.280	0.541**	0.052	0.113
	(0.301)	(0.329)	(0.312)	(0.194)	(0.234)	(0.282)	(0.107)	(0.119)
Number of children (0-5) years	-0.336***	-0.038	-0.337***	0.058	-0.113	0.892**	-0.364***	0.462***
	(0.338)	(0.397)	(0.322)	(0.251)	(0.273)	(0.304)	(0.133)	(0.155)
No of mature *Hass* trees	0.050	0.080**	0.077**	-0.029	0.073***	0.325**	0.030**	0.240***
	(0.037)	(0.038)	(0.032)	(0.029)	(0.026)	(0.025)	(0.014)	(0.111)
No of mature *Fuerte* trees	0.147	0.061	0.075	0.049	-0.114	0.002	0.080	0.042
	(0.164)	(0.038)	(0.136)	(0.103)	(0.106)	(0.085)	(0.069)	(0.042)
Non-labor income (Ksh)	0.135	0.604***	0.205	-0.572	-0.063	0.136	0.166***	0.199***
	(0.222)	(0.161)	(0.169)	(0.087)	(0.139)	(0.130)	(0.062)	(0.066)
credit constraint (yes=1)	-2.948***	-2.544**	-0.833**	-3.616***	-0.341	-1.670*	-0.454	-1.222**

	(0.918)	(1.168)	(0.953)	(0.892)	(0.914)	(1.010)	(0.473)	(0.510)
Number of avocado group meetings	0.159**	0.085**	0.214***	-0.029	0.108***	0.136***	0.013	0.047**
attended in a 12 months	(0.043)	(0.048)	(0.049)	(0.034)	(0.049)	(0.038)	(0.016)	(0.021)
Voted in avocado group elections	4.013***	1.920	1.949**	2.080	1.517**	1.224	1.120***	0.340
(yes=1)	(0.978)	(1.180)	(1.000)	(0.734)	(1.046)	(0.907)	(0.376)	(0.388)
Attended training on avocado agronomy	0.591	0.196**	0.214	0.029	0.908	0.772**	0.297	1.344***
& marketing (yes=1)	(1.455)	(1.559)	(0.049)	(0.034)	(0.993)	(0.952)	(0.412)	(0.472)
[Female F(14, 1088)] [Male F(14, 1094)]	5.51	5.02	5.05	5.14	3.74	4.85	2.92	4.32
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Log pseudolikelihood	-4590.16	-461.80	-4630.23	-2500.81	-4606.14	-4079.78	-2759.35	-2736.87
Observations	1,078	1,084	1,078	1,084	1,078	1,084	1,078	1,084

Robust standard errors in parenthesis, *, **, *** Significant at 10%, 5% and 1%

3.5 Summary, conclusion and policy implications

3.5.1 Summary

Farmers face gender differentiated unique social and economic circumstances which may in part determine their time allocation behavior. Various empirical studies have tried to unpack factors that influence the intra-household pattern of time allocation. This study builds on previous gender time studies and contributes to the literature by investigating factors influencing gendered pattern of labor allocation in avocado production and other inter-related economic activities as well as the intensity of time use. Moreover, unlike previous studies that present differences in gender profile of agricultural activities as descriptive or simple differences in mean, this study has provided quantifiable econometric estimates of drivers that may influence these differences.

This essay employs the double hurdle two stage decision making model and the Tobit model on cross sectional data collected from 790 avocado farming households in Murang'a County, Kenya. The differences in mean test conducted for 1,109 adult females and 1,086 males found no systematic difference in share of female and male labor allocated to avocado production, other crop farming, non-farm self-employment and wage employment. Analogous to the above, we found no significant gender difference in mean time allocated to avocado contract farming activities such as land preparation, weeding and harvesting. We however established significant gender differences in avocado marketing with males at the upper end.

Using separate estimations for each gender, the study found that males differed from females in a number of important ways in factors that influenced their labor allocation decisions. Males increased participation in wage employment while female engaged in avocado and non-farm self-employment reduced as they aged. Education had no significant effect on female labor decisions but increased the chance of male participation in avocado production. In households headed by males, the probability of male participation in wage employment was higher than females. Aging of the household head reduced female labor supply in wage employment and avocado production but increased participation in non-farm wage employment.

Household heads that practiced farming as the main occupation had a higher probability of participation in other crop farming with less labor supply going to wage and non-farm self-employment by both males and females. Females from households with young children aged five years and below, unlike their male counterparts, were less likely to supply labor to wage employment. Results also indicated that household assets and financial endowment increased both male and female participation in avocado production and reduced same in wage employment. Total livestock units owned increased male participation in other crop farming but this association was not different from zero for females. Credit constrained females participated more in non-farm self-employment but the effect was not significant for males. Membership to community groups had varying effects on participation incentives for both male and females, but distance to the market reduced the chances of female participation in wage employment without seeming to affect male participation.

Both conditional and unconditional elasticities of time use suggested that while there are some similar patterns in time use by both genders, there are several important variations in the level of participation in various activities. Education increased the probability of more male time use in other crop farming and less in wage employment. In contrast, education does not seem to influence female time use. Both genders spent more time in non-farm self-employment but reduced their time in avocado production when the household has young children. Estimations indicated that while males and females increased their intensity of participation in avocado production with increase in assets and endowment, females further diversify their time share in non-farm self-employment.

Non-labor income positively influenced the intensity of female time share in avocado production but no effect was noted for males. Both males and females increased their time share in avocado production when the household allocate more land to avocado production. Unlike males, credit constraints reduced the intensity of female time use in avocado production. Both groups reduced their time use in wage employment and non-farm self-employment when they are members of farmer's groups.

Analysis of gender role in avocado contract farming showed that contract farming increased participation of both male and female farmers at all stages of production with the exception of marketing which had a negative but statistically insignificant coefficient for females. The involvement of females especially in harvesting suggested a shift in gender roles. Other factors such as education, marital status, the presence of children under five years, the amount of *Hass* trees a household owned, the number of meeting a farmer attended in the last twelve months and voting in avocado group meetings. Training played a positive role in male participation in various tasks while the variable was not statistically significant for females. And credit constraints reduced participation and time use for both males and females in almost all tasks.

3.5.2 Conclusion

The objective of this study was to analyze factors that influence gender patterns in labor allocation in avocado production and other economic activities in Kenya. Several findings emerged from estimations that have significant implications for the understanding of gendered labor allocation behavior. The study has shown that increase in male education boosts incentives for participation in avocado production but reduced time use in wage employment. This implies that with modernization of agricultural value chains, education is an imperative asset in avocado contract farming.

Young children in the household had a more disabling effect on female involvement and time use in avocado production and wage employment than males. Credit constraint was found to be a barrier to female avocado production. The implication is that credit-constrained females may be left out of the export market and from the benefits of a sector with potential for growth. Household asset endowment and non-labor income were important correlates in providing incentive and capacity for undertaking avocado production and non-farm self-employment. We found that both males and females spent more time in avocado production than in other economic activities. This result showed complementarity in avocado production and other economic activities. Extending the analysis to the role of gender in avocado contract farming, the results indicated limited participation of women in avocado marketing. This suggests that women farmers were not well integrated in all aspects of avocado production.

Avocado contract farming increased the demand for both male and female labor. However, with contract farming, women are now performing roles that were traditionally played by men. This suggests that innovative strategies should be put in place to help women mitigate challenges that they could experience in performing traditional male tasks. Training played an important role in male task performance, but due to the exclusion of female farmers from training, this variable was insignificant for all tasks.

3.5.3 Policy implications

This essay has established that age, young children under five years in households and resource constraints affect male and female labor decisions differently; hence, policy aimed at improving the size and quality of the rural labor force should ensure that the needs of women and men farmers are addressed differently to ensure that women farmers are not disadvantaged in production.

The positive correlation between avocado production and male education as well as the intensity of time spent by both gender in avocado production suggest that avocado production presents a viable employment opportunity for rural communities; thus policy makers should promote smallholder avocado production by providing incentives that will enable women and youths to produce avocado. This will ensure consistent supply of avocados to meet market demand and may also deal with gender disparity in marketing.

Due to the complementarity and interrelatedness among avocado production, non-farm self-employment and wage employment, policy and strategies aimed at promoting avocado production should include programs that will also improve non-farm self-employment and wage employment. For instance grading and sorting facilities can be provided in the community where avocados are sorted and weighed before taking it to the exporter where there are none. This could minimize farmer's transporting of rejected avocado. It could also provide wage employment opportunities.

The increase in participation and time use in avocado production tasks due to contract farming suggests the county government and other non-governmental agencies involved in agricultural should ensure more smallholder involvement in contract farming by linking them with exporters. Women's involvement in roles traditionally played by men as a result of contract farming also suggests the need for innovative strategies that could address their constraints. This could be done through dialogue between extension workers and female famers to identify their constraints in performing those tasks.

Although both men and women are involved in avocado production, women were mostly excluded from training provided by exporters since they do not own the avocado trees. We therefore recommend that government should partner with exporters to implement avocado agronomy and GAP training so that women farmers will also benefit from those trainings. Incorporating women farmers in trainings would enhance their efficiency and the quality of fruits produce.

CHAPTER FOUR: THE EFFECT OF WOMEN'S EMPOWERMENT IN AGRICULTURE ON FOOD SECURITY IN KENYA

4.1 Introduction

Achieving food security is the global agenda of Sustainable Development Goal 2 which bestows responsibility on national governments and stakeholders to ensure food security for all (UN, 2015). The current thinking of way forward for sustained food security is for farmers to produce more food per unit of available land within a healthy ecology (UN, 2015). At the core of the discussion is how social-economic inequalities between men and women farmers can be reduced so that women farmers who are major stakeholders in agriculture can contribute to this drive. Growing empirical evidence speaks of an intrinsic link amongst women's empowerment sustainable agriculture, food security and rural poverty reduction. The operationalization of this inter-linkage is transmitted through increased productivity and rural income (Doss, 2014); more and cheaper food for both urban and rural dwellers as well as improved nutrition and child health (Duflo, 2012); increased contribution of agriculture to growth and other economic opportunities in non-farm sector (DFID, 2004).

In alignment of the global zero hunger goal to the national goals, the National Food and Nutrition Security Policy (Republic of Kenya, 2011) defined food security "as a situation in which all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life". Against this backdrop, the government has implemented several policies and strategies to spur agricultural led growth and food security. The Agricultural Sector Development Strategy (ASDS) 2010-2020 which is pitched on Kenya's development blue print vision 2030 are among major policy intervention for the growth of the agriculture sector (Republic of Kenya, 2010). Besides these long term policy frameworks, the government has undertaken policy responses such as the provision of input subsidies, price and supply related policy interventions to address the range of issues affecting food production, prices and affordability.

Despite these interventions and slight improvements in economic growth, the country is still grappling with food insecurity, with about 2.6 million Kenyans suffering from severe food insecurity and malnutrition (Republic of Kenya, 2018). These food insecurity incidents have been attributed to factors such as droughts, high prices of commodities, weaker purchasing power and high costs of domestic food production among others. Besides these factors, the full potential of women who provide between 42 percent and 65 percent of the agricultural labor has not been utilized (Republic of Kenya, 2010). For instance, only 1 percent of women have land title deeds and they receive only 7 percent of extension services (World Bank; 2013a). Women are also disadvantaged in terms of credit, other asset ownership, extension services, education and health care services (World Bank, 2015c). Kenya's food insecurity situation could be much improved if women farmers are fully empowered both at the community and national level. Empowering women in agriculture will not only make them financially independent, but make them engines of Kenya's future growth and the conduit to food security. Women empowerment is however a multifaceted process (Malhotra et al., 2002). Thus identifying the ways in which women's empowerment enhance food security is essential for informed food security policies in Kenya.

There are a number of reasons to hypothesize that empowering women in agriculture may enhance food security. In most instances, women who are empowered tend to have greater bargaining power in production and household decision making. More so, empowered women are in most cases educated which may allow them to use productive resources more efficiently. Research also suggests that women's control over productive resources are likely to improve the welfare of children (Quisumbing and Maluccio, 2003; Quisumbing and Hallman, 2003). A number of studies using the women's empowerment in agriculture index -WEAI have also established a significant relationship between empowering women in agriculture and food security - (Malapit et al., 2013; Sraboni et al., 2014; Malapit and Quisumbing, 2015).

These studies used conventional objective food security measures such as caloric intake and other anthropometric outcomes from consumption or expenditure data. Using caloric intake as a measure of food security is however challenging since individual caloric requirements depends on their age, size and other considerations. This variability may lead to inconsistency in estimation of caloric needs for different population groups (Maxwell et al., 2014). Also, caloric intake measure reflects current consumption which does not consider food quantity and the actual food insecurity experience of households (Barrett, 2010). On the other hand, anthropometric measure like stunting does not have a direct link to food security, since stunting may reflect past history rather than current food security situation. Moreover, most consumption data used for objective measures exhibit seasonal volatility which may not present the actual picture of food security situation (Barrett, 2010).

These drawbacks, coupled with the technical difficulty and cost intensity of objective methods in providing adequate food security measure, have shifted the attention of food security analysis to the access component and subjective measures which provides different contextual information of food security. The access dimension of food security encompasses access to infrastructure, ability to generate income and control over productive resources (Maxwell et al., 2014). Unlike objective food security analysis which is focused on conditions of deprivation, subjective measure analyzes feelings of deprivation. It captures household self-assessment of their food insecurity situation and provides welfare-relevant information that could not be obtained in standard objective data (Ravallion and Lokshin, 2002). Subjective indicators are now increasingly important in measuring the food security situation of vulnerable populations, determining early warning signs and for the monitoring and evaluation policies and programs (Maxwell et al., 2014). The importance of subjective measures have prompted arguments for the wider application of its use in international food security and monitoring surveys (Deaton, 2010)

Efforts in identifying households at risk of hunger and food insecurity through experience-based food insecurity (access) mostly used the coping strategies index, the Household Food Insecurity and Access Scale (HFIAS), the Household Hunger Scale (HHS) and the Food Insecurity Experience scale (FIES). The Coping Strategies Index (CSI) is mostly used to capture food security dynamics and strategies used to augment resource in rural households. The weakness of this index is that strategies households resort to such as taking high interest loans, selling of productive assets or out-migration vary by household type, culture and across countries which makes the identification of a commonly question that captures the various facets very difficult (Coates et al., 2007). The Household Hunger Scale measure is a subsidiary of the Household Food Insecurity and Access Scale (HFIAS) while the Food Insecurity Experience scale (FIES) is mostly used to investigate national food security level.

The HFIAS is an updated version of the United States Household Food Security Survey Module (US HFSSM) to reflect developing country context and to describe behaviors and attitudes of food security. The measure is useful in detecting shocks and seasonality issues related to food security (Headey and Ecker, 2013). Various multi-country studies (Maxwell et al., 2014; Ali, et al., 2012; Headey and Ecker, 2012), suggests that the HFIAS measure picks up nutrition relevant information like other objective measures thus, making the HFIAS one of the best and most widely used subjective measures in international contexts.

Understanding household food insecurity situation by explicitly framing out the effect of women's empowerment in agriculture through HFIAS measure is important for several reasons: i) the measure captures the effect of women's empowerment on both the physical and psychosocial dimensions of food security; ii) it helps us to quantify the relationship between women's empowerment in agriculture and the food insecurity experience of affected individuals; iii) the experience based method provides a means for understanding the causes and consequences of food insecurity and hunger through the mapping and identification of food insecure households and, iv) the HFIAS methodology and scale are applicable in diverse sociocultural settings. Some studies (Kabuga et al., 2014; Murendo and Wollni, 2016; Kimani-Murage et al., 2014) have applied the HFIAS tool to assess the food insecurity situation in various developing countries. These studies however did not account for the role of women who are the major contributors in the agricultural sector; thus findings may not be well informative for effective policy geared towards achieving food security.

This study fills in the gap by exploring the relationship between women's empowerment in agriculture and household food security. The essay contributes to literature on food security and women empowerment discussion on three fronts. First controlling for potential endogeneity, this study provides quantifiable evidence from Kenya on the relationship between women's empowerment in agriculture and household experiences in terms of insufficient food quality, quantity and uncertainty leading to hunger and food insecurity. To the best of our knowledge, this is the first time WEAI has been analyzed in this manner and in Kenya in particular. Second, the essay presents analysis of how each component of the women's empowerment score is associated with food security. Lastly, previous studies (Malapit et al., 2013; Srabon et al., 2014; Malapit and Quisumbing, 2015) did not control for non-linearity of the women's empowerment score. Papke and Wooldridge (1996) indicate that such non-linear bounded variables are likely subject to floor and ceiling effects, which in most cases display non-constant responses to changes in the predictors as they approach the bounds. This essay corrects for the non-linearity of the women's empowerment variable and demonstrates that misspecification of the functional form of the empowerment variable leads to overestimation of its true effect on the outcome of interest.

4.1.1 Research questions

The study is guided by the following research questions:

i. What is the effect of women's empowerment in agriculture on household food security?
ii. How are the component indicators of women's empowerment score associated with food security?
iii. What are the policy implications of the research findings?

4.1.2 Study objectives

The overall objective of this essay was to examine the relationship between women's empowerment in agriculture and food security.

The specific objectives were:

i. To investigate the effect of women's empowerment in agriculture on food security.
ii. To assess how component indicators of women's empowerment score are associated with food security.
iii. To suggest policy recommendations based on research findings.

The rest of the essay is organized as follows: Section 4.2 presents theoretical and empirical literature on women empowerment and food security. Section 4.3 presents methodology, data and descriptive statistics. Section 4.4 present the results while section 4.5 presents summary, conclusion and policy implications.

4.2 Literature review

This section presents both theoretical and empirical literature on the effect of women's empowerment on food security. Subsection 4.2.1 presents theoretical foundation of intra-household resource allocation; 4.2.2 presents empirical literature review; while 4.2.3 presents summary of literature review.

4.2.1 Theoretical foundation of women's empowerment

The concept of women's empowerment is anchored on theories of development and poverty reduction. The basic premise is that economic growth could be achieved with policies that could benefit the poor from participation in the process of growth while society benefits from their output. Women's immense contribution to society prompted a further debate in the development agenda on how to correct gender inequalities that disadvantage women's participation in the growth process. The debate gravitated towards various theories of women empowerment most of which are pitched on household dynamics within which economic decisions are made. The unitary model has been traditionally used to model household decision-making (Becker, 1965). However, sufficient empirical evidence points to the weakness of the model's assumptions that treats households as a single decision making unit pooling their resources together. Moreover, the model does not consider gender based inequality in resource ownership within the household which results in substantial differences in the amount of power an individual wields in decision making on resource allocation (Behrman, 1988). Women's vulnerable position in terms of resource ownership puts them in a weaker bargaining position to make decisions on their priorities and needs.

The bargaining model was developed to address some of the short-comings of the unitary model. It relaxes the assumptions of preference aggregation by treating household members as individuals with their own rational preferences. The unifying principle behind the model is that an individual's ability to influence decisions within the household depends on exogenous increase in autonomy from command of resources outside the household. For instance, women's ownership of assets or non-wage income provides economic security and improves her bargaining power and the welfare of other household members. There are various variants of the collective models, the main being cooperative and non-cooperative. The chief proponents of the cooperative bargaining model are; Manser and Brown (1980), McElroy and Horney (1981), Lundberg and Pollak (1993) and Chiappori (1988); while the proponents of non-cooperative model are Ashworth and Ulph (1981). Our study adopts the cooperative bargaining framework because it explicitly allows investigation of intra-household heterogeneities in resource allocation. It is assumed that both men and women collectively combine their capacities and resources to provide for the household, but they do so in ways that reflect their common and differing priorities. Using this framework, we expect that household food insecurity may vary depending on the woman's bargaining or decision-making power in the household.

4.2.2 Empirical literature review

Women's empowerment is a complex concept with different socio-economic and cultural dimensions. This complexity has occasioned the various definitions and measurements of women's empowerment. The concept of "process" and "agency" however cuts across the various definitions. This study adopts the definition of Kabeer (1999) who defines women's empowerment as expanding women's ability to make strategic life choices, particularly those who have been denied such ability. The concept of choice within the definition can be explored through three closely interconnected facets of agency, resources, and achievements. The significance of women's empowerment in development literature has drawn growing empirical research to the relationship between women's empowerment in agriculture and various food and nutrition indicators.

For instance, studies from Nepal by Malapit et al., (2013) assessed the relationship between production diversity, maternal and child nutrition outcomes and women's empowerment. Results from instrumental variable estimates showed that women's empowerment had a significant effect on mother and child nutrition outcomes as well as dietary diversity. The authors however concluded that the effect of individual women's empowerment indicators did not overlap. Although informative, the study does not assess the emotional state of uncertainty or anxiety over food, nor does it categorize households according to the severity of food insecurity situation. Moreover, the treatment of women's empowerment score as a continuous variable has the potential of overestimating the impact of WEAI on the outcome variable. This has been addressed in our study by employing estimation techniques that account for non-linearity of the women's empowerment variable.

Similarly, Sraboni et al., (2014) examined the link between women's empowerment in agriculture and food security in Bangladesh. The authors used both instrumental variables (IV) and ordinary least square (OLS) estimators. Their result indicated that women's empowerment significantly influenced dietary diversity and calorie availability. This effect was transmitted through the number of group activities women participated in, and the number of assets women controlled. Although their study provides information on food security, the method which is based on simple counts of food groupings do not capture the psychological aspect of those affected by food insecurity. Like Malapit et al., (2013), the study did not control for the non-linearity of the women's empowerment variable but instead treated it as a continuous variable. In our model however, we correct for this by using HFIAS measure of food security and also account for non-linearity of the empowerment variable.

Malapit and Quisumbing (2015) also assessed the linkage between food security and women's empowerment in agriculture in Northern Ghana, using anthropometric indicators of food security. Estimates from the OLS regression showed that women's empowerment score, gender parity gap indicator and input in credit decisions did not influence the likelihood of exclusive breast feeding for both girls and boys; however, women's input in production decision was positively correlated with girl's breast feeding practices. The empowerment score and empowerment in production decision domain were negative and significantly related to girl's diet diversity score while none of the empowerment variables were significant for boys. The overall result suggested that the influence of women's empowerment indicators varied by gender of child. Due to potential endogeneity of empowerment variables and unavailability of suitable instruments, the authors cautioned that estimates can be interpreted as associative rather than causative. Our study addresses this drawback by accounting for endogeneity and exploiting model heteroscedasticity to construct instruments in instances where valid instruments are not available.

Seymour et al., (2016) assessed the relationship between the adoption of improved maize variety and women's empowerment in agriculture using survey data from Ethiopia, Kenya and Tanzania.

Pooled regression estimates from the double hurdle model showed no significant association between the adoption of improved maize variety by farmers and women's empowerment score. The probit estimates however showed that women's input in decision making over production and assets ownership were channels through which women's empowerment influenced implementation of improved maize and acquisition of credit for adoption. Although the study of Seymour et al., (2016) provides valuable insight on other dimensions through which women's empowerment influence agricultural production it does not explicitly provide information on household food security situation.

Following similar line of thought, Diiro et al., (2018) researched the correlation between agricultural productivity and women's empowerment in agriculture using cross sectional data from western Kenya. The authors used control function method to estimate the effect of WEAI on maize productivity. Findings point out that women's empowerment was significantly related to agricultural productivity. Although this study used estimation procedure that controlled for non-linearity of women's empowerment score, it did not explicitly explore the influence of women's empowerment on food security.

A number of other studies have also investigated the determinants of food security using HFIAS measure but without investigating women's empowerment. For instance Kabuga et al., (2014) assessed the impact of adopting tissue culture technology in banana production on household food security and income in Central and Eastern Kenya. Estimates from both OLS and IV methods showed that education and asset ownership significantly lowered household food insecurity while household size and credit constraint were noted to increase food insecurity. For the severely food insecure, age, off-farm income share and credit constraints increased the severity of their food insecurity status while assets did the opposite. Although this study used the HFIAS measure of food security, it did not explore how women's empowerment may impact food security.

Using three rounds of survey data from the Nairobi Urban Health and Demographic Surveillance System (NUHDSS), Kimani-Murage et al., (2014) investigated factors associated with vulnerability to food insecurity of slum residents in Viwandani and Korogocho in Nairobi, Kenya. The authors constructed a binary indicator of food security using eight out of the nine HFIAS indicators. The study found that household income, source of livelihood and household size where positively correlated with food security while dependency ratio, illness perceived insecurity and being residence in the slum reduced the probability of food security. Even though the study used the HFIAS measure of food security, it did not consider women's empowerment in agriculture.

Murendo and Wollni (2016) investigated the relationship between mobile money and household food security in Uganda using HFIAS score and binary food security indicator. Both the OLS and IV probit estimates indicated the significant role that mobile money played in reducing food insecurity. Other covariates such as ownership of transport and land were also important in reducing food insecurity. Group membership also reduced food insecurity in the binary food security outcome. Like previous studies (Kabuga et al., 2014 and Kimani-Murage et al., 2014), this study did not examine how women's empowerment could influence food security.

Looking at the gender perspective, Kassie et al., (2014) assessed factors that determine the food security situation of households headed by men and those headed by women in Kenya. The study used household's self-assessment of vulnerability and sustainability as a measure of food security. The authors used endogenous switching regression estimation techniques. Results from the analysis showed that households with female heads were more food insecure compared to their male counterparts. Covariates such as quality of extension workers, farm size, land quality, manure and chemical fertilizer use and rainfall were significant determinants of food security. These effects however varied between the two groups. For instance the quality of extension workers was a positive and significant predictor of female headed household food security while it did not statistically influence food security situation of households headed by men. Although Kassie et al., (2014) assessed the gender dimension of food security; their study did not analyze the effect of women's empowerment in agriculture on food security.

4.2.3 Summary of literature review

The unitary model is historically the dominant framework for modelling intra-household resource allocation. Due to limitations of the model's assumptions, a number of alternatives to the unitary model such as the bargaining model have emerged. The advantage of these models over the unitary model is that they allow for differing preferences and utility functions of individuals within the household. The empirical literature revealed that empowering women in agriculture enhances food and nutrition security (Malapit et al., 2013; Srabon et al., 2014; Malapit and Quisumbing, 2015). Other studies (Seymour et al., 2016: Diiro et al., 2018) also showed the vital role of women's empowerment in influencing the adoption of improved seed varieties and agricultural productivity. A major estimation issue reported by these studies is endogeneity of the women's empowerment variable. Consequently, instrumental variable (IV) method has been the most prevalent estimation technique used for model identification.

Other studies that analyzed the determinants of food security using HFIAS measures showed that education and asset ownership (Kabuga et al. 2014), household income and source of livelihood (Kimani-Murage et al., 2014) lowered food insecurity. Other factors that explained food security include: adoption of mobile money, land size, ownership of transport means and group membership (Murendo and Wollni, 2016), quality of extension workers, land quality, manure and chemical fertilizer use and rainfall (Kassie et al. (2014). Factors that increased household food insecurity were: household size and credit constraints (Kabuga et al., 2014), dependency ratio, illness, and slum residency (Kimani-Murage et al., 2014).

One of the short comings of the studies is that they treated the women's empowerment score as linear and thus estimated its effect using two stage ordinary least square methods (Malapit and Quisumbing, 2015; Malapit et al., 2013; Srabon et al., 2014). First stage estimation using OLS as in the standard IV produces predicted values that lie outside the interval, which produces erroneous effects on the outcome variable. Moreover, these studies used food measures such as dietary diversity and caloric intake that captures neither household's food insecure risk nor vulnerability and changes in their food security position over time. The studies of (Diiro et al., 2018 and Seymour et al., 2016) are not based on food security while the studies of (Kabuga et al., 2014; Kimani-Murage et al., 2014; Murendo and Wollni, 2016; Kassie et al., 2014) did not examine the relationship between women's empowerment and food security. Our study accounts for this pitfall by using estimation strategy that accounts for non-linearity of women' empowerment score. We also use the HFIAS measure of food security that captures the food insecurity experience of households. With the non-availability of appropriate instruments, we use alternative identification methods such as exploiting model heteroscedasticity for identification which produces robust results.

4.3 Methodology

This section presents both the theoretical and empirical methods employed in this essay. Subsection 4.3.1 provides the theoretical model; 4.3.2 presents the empirical model while 4.3.3 presents definition and measure of variables.

4.3.1 Theoretical framework

In our theoretical model we assume that a principal male and female in a farm household have their individual preferences and utility functions. They maximize their individual utility by consuming a vector of goods both purchased and produced C, leisure L^i and a vector of household characteristics ϖ. Each individual has a treat potential or bargaining power V^i which is jointly maximized by cooperation. Following Mendoza and Berlage (2002), the utility maximization of the gain from cooperation of the two individuals $i \in \{m, f\}$ is specified as:

$$Max[\mathrm{U}^m(\mathrm{C}^m, \mathrm{L}^m : \varpi) - V^m][\mathrm{U}^f(\mathrm{C}^f, \mathrm{L}^f : \varpi) - V^f] \quad (4.1)$$

The threat point

$$V^i = V_i(p_q, p_x, p_c, w_i, A_i, l_i) \quad (4.2)$$

The threat point V^i which influences the bargaining authority of the individual's within the household depends on the price of farm output (p_q) the price of purchased good (p_c) price of farm inputs (p_x) market wage (w_i) the household's farmland A, that can either be jointly owned or land owned by each spouse before marriage and brought into the union and non-labor income (l_i). The spouses maximize their individual utility subject to time constraints, production and budget constraints. The time constraint function is specified as:

$$T = L^i + F^i + M^i \quad (4.3)$$

Where T represents total household time endowment allotted to leisure L^i, production of farm goods F^i and off-farming activities M^i. A non-negativity constraint is imposed for farm and off-farm activity $F^i \geq 0,\ M^i \geq 0$, $\forall i \in \{m, f)$.

Farm output Q is produced from a production technology that is expected to be concave and twice differentiable, with male and female farm labor F^m, F^f, inputs used in production X, agricultural land A and a vector of production technology characteristic ζ . Assuming a positive marginal influence of each factor to output, the production function is written as:

$$Q = G(F^m, F^f, X, A : \zeta) \quad (4.4)$$

The spouses receive profits (π) from farm production which is equal to $\mathrm{P}_q Q - P_x X$. They also receive market wage from off-farm earning w and non-labor income I^i . These income or revenue accrued is equal to consumption expenditures $P_c C$. Where P_q is the price of goods produced from the farm, and P_x is composed of prices of farm inputs. The budget constraint is specified as:

$$\pi + w(\mathrm{M}^m + M^f) + I^m + I^f = P_c C \quad (4.5)$$

The production constraint (4.4) is then joined with the income constraint (4.5) to obtain

$$(P_q G[F^i, X, A : \zeta] - P_x X) + w(M^m + M^f) + I^m + I^f = P_c C \quad (4.6)$$

. The Lagrangean for the constrained optimization problem for the spouses is indicated as:

$$L = [U^m(C, L^m) - V^m][U^f(C, L^f) - V^f]$$

$$\lambda\{[P_q Q[F^m, F^f, X, A : \zeta] - P_x X) + W^i(M^m + M^f) + I^m + I^f - P_c C\} + \gamma^i(T^i - L^i - F^i - M^i) \quad (4.7)$$

Where λ , γ^i are Langrange multipliers for the marginal value of income and household time Assuming an interior solution, the first order Kuhn Tucker conditions are shown in appendix 3

From the first order condition the spouses' labor supply function to farm production F^i is a function of prices of purchased good (p_c),farm output (p_q) price of farm inputs (p_x) market wage (w_i), household's farm land, A and spouse's non-labor income (l_i).

$$F^i = F(P_c, P_q, P_x, W^m, W^f A, I^m + I^f) \quad (4.7)$$

In the bargaining model, equation (4.2) is added to the farm labor supply function as follows:

$$F^i = F(P_c, P_q, P_x, W^m, W^f A, I^m + I^f, V^m, V^f)$$
(4.8)

Where V^m and V^f denote the threat point or bargaining power of each spouse as specified in equation (4.2)

This can be reformulated as:

$$F^i = F(P_c, P_q, P_x, W^m, W^f A, A^m, A^f, I^m + I^f + I^m + I^f) \tag{4.8}$$

Unlike in the unitary framework in equation (4.7) where land and non-labor enter the model as components of household endowments; in the bargaining model, inherited land A and non-labor income I^m and I^f goes into the labor supply function in two ways; land enters in the first instance as an element of the land owned by the household as a unit and secondly as a personal property of each spouse such that in the case of marriage break-up the owner can take possession of it. Likewise non-labor income goes into the model initially as a component of a couple's non-labor income and then as a separate determinant of each spouse's threat point. In the case of our study, the bargaining power or threat point enters the model as the varying degree of independence or control women have over assets, production and outputs from production decisions.

4.3.2 Empirical analysis

The empirical analysis for this essay is divided into three sub-sections. Sub-section a) discusses the construction of women's empowerment index. The index is our main variable of interest for the food security equation. Women empowerment is expected to play a substantial role in lowering food insecurity. Sub-section b) discusses the how food security is measured. The household food security was operationalized into two measures; the Household Food Insecurity Access Scale (HFIAS) score and Household Food Insecurity Access Prevalence (HFIAP) categories. Sub-section c) presents econometric approaches used. In the econometric analysis, two alternative specifications of food insecurity were estimated. In the first estimation, food insecurity was estimated as an index, with the general effect of women's empowerment on food insecurity evaluated as both an aggregate score and as disaggregated indicators to evaluate their individual effect on food insecurity. The second food insecurity specification was based on the effect of the aggregated women's empowerment index on (HFIAP) categories.

a) Women's empowerment in agriculture index

The WEAI is a new survey-based tool that builds understanding on the linkage between food security, agricultural growth and women's empowerment. It focuses on women's "agency" or ability to define goals and act upon. WEAI captures women's control over resources in agriculture, which other indices such as the Gender Gap Index and demographic and health surveys do not (Alkire et al., 2013). The index also has the advantage of being decomposable to assess how each indicator contributes to women's empowerment or disempowerment. Although WEAI was developed to follow-up on changes in women's empowerment in the United States Feed the Future program, the tool has gained wide applicability by development organizations, academics and policymakers, to identify gender based constraints that tend to exclude women in the agriculture sector.

The WEAI index is computed based on data collected from both principal female and male respondents in the same households. It contains two sub- indexes: The first sub indicator is the five domains of women's empowerment (5DE). It measures the extent to which women are empowered in their communities with regards to decisions making about 1) agricultural production, 2) access to productive resources and decision making on their usage, 3) control over how income from production is used, 4) leadership role in the community, and 5) time use. The second sub-indicator, gender parity index (GPI), measures the empowerment of women relative to the principal male in their household. This sub-index compares the 5DE for females and within the same household.

The WEAI indicators continue to evolve overtime. The original 5DE of WEAI is based on a weighted index of ten indicators. The redefined version of WEAI referred to as A-WEAI still maintains the five domains of women's empowerment but has reduced the indicators of the 5DE to six (Malapit et al., 2017). Like the original version, A-WEAI is constructed from individual-level survey data. Even though the WEAI is a weighted sum of 5DE and GPI, our measure of women's empowerment is based on the 5DE only. The 5DE for males was not computed due to some missing values of WEAI indicators. By WEAI definition, individuals with missing data for any of the WEAI indicators are dropped. This lowered the sample for males and limited our ability to construct the GPI. The absence of the GPI does not affect our analysis since in terms of capturing women's empowerment; the 5DE explains 90 percent while the GPI explains 10 percent of the weighted WEAI (Alkire et al., 2013). Moreover, our focus was on women since disempowerment of women is pervasive and more complicated compared to men. As such, the issue of empowerment is more pertinent to women since intra-household affairs are main sources of women's disempowerment (Malhotra and Schuler, 2005). The 5DE constructed for women followed the same underlying methodology of A-WEAI (Alkire et al., 2013: Malapit et al., 2017). Since our data did not have the time domain, we used the adjusted version of the A-WEAI to construct the 5DE.

The production domain indicator was constructed by evaluating women's response to questions on participation and how much input she had in decision making in livestock raising, food and cash crop farming. A sub indicator that considers the individual adequate if she participated and made some input in decision making on that activity was created for each activity. The input in productive decisions indicator was then composed by aggregating the various sub-indicators. A woman was then considered adequate in the production domain condition on having made inputs in at least two types of decisions.

Women's adequacy in the resource domain indicators were also created by examining women's response to sole or joint ownership of land, large and small household durables as well as decision making about credit. For the asset indicator, a sub indicator was created that assigns a value of one to a woman if she confirmed to have sole or joint ownership of any of the items listed above, if the household has those assets. These indicators were then aggregated across assets, given the number of assets that the household owns. Accordingly, a woman was considered empowered in ownership domain if she owned at least one asset, provided it is not simply small livestock like pigeons, chicken, turkeys or ducks and small consumer durables or non-mechanized farm equipment.

For the credit indicator, the respondents were first asked whether they needed credit. This question separated respondents who did not obtain loans because they did not need it and those who needed credit but could not get it. Only the latter should be considered credit constrained. Measuring access to credit based solely on whether or not respondents have taken out a loan

(without considering need) runs the risk of overestimating the actual proportion of the population that is credit constrained. To be considered adequate for the decision making on credit indicator, the respondent should have needed credit and obtained same from formal and\or informal sources in the previous year and should have contributed in making least one decision about it.
The control over income domain looked at input in decisions made on the use of income from farm production earlier indicated in the production domain, economic activities other than farming, wage or salary employment and decisions on small and major household expenditures. Sub-indicators were created and then aggregated into an overall indicator of adequacy on control over income. A woman was considered empowered in the income domain and given the value one if she made at least one decision on the use of income for household expenditure as long as it was not a minor expenditure.

The group membership domain captured the woman's influence in her community and leadership potential. A woman was considered adequate in that domain if she was an active member of any agriculture-related social or civic group in her community. In instances where there are no groups in the community, she was considered not empowered in that domain.

Following Alkire et al., (2013) and Malapit et al., (2017), the overall empowerment score for each woman was derived by multiplying each of the above indicators by the weights indicated in Table 1 as follows:

$$Empowerment_i = w_{1i}P + w_{2i}R + w_{3i}I + w_{4i}G \quad (4.9)$$

Where w's are weights, P, R, I, G are production, resource, income and group membership indicators and i denotes individual woman. The A-WEAI weights are weights assigned by the A-WEAI methodology while the adjusted weights were constructed based on the four indicators. For the resource domain assigned A-WEAI weights were expressed over the total adjusted weight (2/15=0.13) and (1/15=0.07). A woman is said to be empowered and given a value of one if she achieved adequacy in at least 80% in the sum of the weighted indicators (Alkire et al., 2013: Malapit et al., 2017).

Table 4.1: The Abbreviated Women Empowerment in Agriculture (A-WEAI)

Domain	Indicator	Definition of indicator	A-WEAI Weights	Adjusted A-WEAI weights
Production	Woman input in production decision	Woman makes sole or joint decisions on livestock, farming and fish production	1/5	1/4
Resource	Woman ownership of assets	Woman solely or jointly owns major assets	2/15	0.13/0.8
	Women access to and decision on credit	Woman has access to and participation in decisions concerning credit	1/15	0.07/0.8
Income	Women control over use of income	Woman sole or joint control over use of income and expenditures	1/5	1/4
Leadership	Group membership	A Woman's active member in at least one economic or more social groups	1/5	1/4
Time	Women workload	A woman worked more than 10.5 hours in previous 24 hours	1/5	

Source : Alkire et al., (2013) ; Malapit et al., (2017)

b) Measurement of food security

Food security is a multidimensional concept defined and operationalized differently in various contexts. Several approaches used to measure food security are based on the pillars of availability, utilization and access, with stability added by some scholars. The availability component reflects the supply side of food security such as food production, stock levels and net trade. This component has been widely used to assess food security but it is limited in terms of capturing unequal distribution and proper utilization of food in the population (Jones et al., 2013). The utilization component is concerned with whether individuals and households make adequate use of the food they have accessed. This dimension is captured through anthropometric indicators such as stunting, wasting and underweight. The anthropometric measure is also limited in that, proxy measures used to measure food security are an interaction between food security and one's health status which may misrepresented food security (Maxwell et al., 2014). The access dimension addresses the demand side of food security. It accentuates household food security situation in responding to adverse shocks such as price spikes, droughts, loss of livelihood or unemployment. The access component of food security is closely related to poverty and socio-economic well-being of the household (Maxwell et al., 2014).

Most developing countries are either food insecure or vulnerable to food insecurity. Food insecurity occurs when households experience uncertainty about sustainable food availability and access required for a healthy lifestyle. Major causes of food insecurity are attributed to disease, poverty, environmental changes, population growth, social exclusion, volatility in food prices and poor market access among others. Food insecurity could be transitory or chronic. Transitory food insecurity is a situation where a person or household suffers a temporary shortage in food consumption whereas; chronic food is a situation where a person or household faces the risk of famine (Massett, 2010). During transitory food insecurity, households may adopt several coping strategies such as depleting productive assets, borrowing and engaging heavily in off-farm job and out-migration which may result to long run chronic food insecurity situation (Massett, 2010).

The HFIAS indicator is the most widely used household self-assessment measure of food insecurity access. Wolfe and Frongillo (2001) however argued that subjective measures are limited in that they do not account for food intake. And that measuring food insecurity from peoples' responses to food insecurity questions may induce intentional bias. The authors asserted that households may exaggerate their food insecurity status to gain more food assistance or they may under report their food insecurity situation if they feel embarrassed about their situation. Despite these limitations, subjective measures have been recognized to be more sensitive to changes in household food insecurity and play a major role in policy interventions geared to addressing household food insecurity (Kirkland et al., 2011). We therefore use the HFIAS approach to generate household food insecurity index from survey information on food security collected from Western and Eastern Kenya.

The Household Food Insecurity Access Scale (HFIAS)

The HFIAS is built on the premise that household's experience of food insecurity could kindle foreseeable responses and reactions that can be captured and quantified through a survey and then summarized in a scale. The level of household food insecurity during the past 30 days is measured by household's self-response to nine occurrences and frequency of occurrence questions as per the food security model (Coates et al., 2007). From this data, we calculated the Household Food Insecurity Access Scale Score and Household Food Insecurity Access Prevalence (HFIAP) for further analysis. See Table A10 in appendix 3 for food security indicators.

According to Coates et al., (2007), the frequency of occurrence question can be summed up to create the HFIAS score for each household. The total score is arrayed from 0 to 27 with the upper limit denoting greater level of food insecurity on the scale. This method has however been criticized on grounds that each sub-domain of the food insecurity question captures different aspects of food insecurity; as such, assigning equal weights to each item regardless of its value or utility may not be informative (Kabunga et al., 2014). Factor analysis is a well-established methodology that has been applied to overcome this weakness (Mckenzie, 2005). We therefore applied principle component analysis (PCA) to capture common patterns in the data and to create a weighted index of all items.

Several analytical tests were carried out to confirm the use of principal component analysis. Result from the Kaiser Meyer-Olkin (KMO) measurement of sampling suitability produced a value of 0.890, while the Bartlett test of sphericity gave a $\chi 2$ = value of 2201.162 (p = 0.000). Both the KMO and Bartlett tests statistics supported the validity and suitability of our data for factor analysis. Also, the Cronbach's alpha statistic which test for the scale reliability to reflect the construct that it is measuring gave a value of 0.9357, exceeding the advisable minimum of 0.7 (Keino et al., 2014). The Eigen vector and scree plot test shows that the first component explained 68 percent of the variance while the second factor explained 13 percent and both cumulatively explained 80 percent of the variance. The two components were rotated to clarify factor patterns for better interpretation of results (see Table A11 appendix 3 for rotated components).

The Household Food Insecurity Access Prevalence (HFIAP) classifies households into four groups according to their level of food insecurity. Households that are considered food secure are placed in category one while the mildly, moderately and food insecure are placed in categories two, three and four respectively. The HFIAP categories were computed following cut-offs defined by Coates et al., (2007). The classifications were based on household's affirmative responses to the frequencies of food insecurity experiences (Coates et al., 2007). Due to little variation in the data between categories two and three, both groups were combined into one category to represent moderately food insecure.

c) Econometric approach

To analyze the effect of women's empowerment on household food insecurity, we estimated two alternative specifications of food insecurity functions. In the first specification, the effect of women's empowerment was operationalized in aggregate to understand the general effect on food security. Then separately for each of the five indicators of women's empowerment to assess their individual effect on the food insecurity index. The second food insecurity specification assessed the general effect of women's empowerment on food insecurity categories.

Assessment of the influence of women's empowerment on food insecurity was based on our theoretical framework and empirical review. We hypothsized that women's empowerment in agriculture reduces food insecurity (Sraboni et al., 2014; Malapit and Quisumbing, 2015). Other controls such as individual and household characteristics (age, educational attaiment, household size, marital status, main occupation, plot manager, land size, livestock ownership), agricultural activities and plot attributes (received adequate extension advice, plot intercropped, adoption of improves variety, adoption of soil conservation, fertile soil, poor soil, deep soil shallow soil) and regional characteristics were assumed as important predictors of household food security (Kassie et al., 2014; Kabuga et al., 2014; Kimani-Murage et al., 2014)

i) Food (in)security and women's empowerment

The study hypothesizes that the association between household food insecurity and women's empowerment is specified as follows:

$$F_i = \alpha + \beta_1 Empowerment_i + \beta_2 I_i + \beta_3 A_i + \varepsilon_i \quad (4.10)$$

Where F_i is the food insecurity index, I_i is composed of household and individual characteristics and A_i is a vector of agricultural activities and plot attributes, $\beta 's$ are unknown parameters to be estimated and ε is the error term expected to have a normal distribution and i indexes individual observations. Equation (4.11) can be estimated using Ordinary Least Square (OLS).

The identification and estimation of the causal effects of women's empowerment on household food insecurity by OLS may be biased if potential endogeneity and individual heterogeneity are not taken into consideration (Wooldridge, 2002). Endogeneity may occur if unobservable factors that influence women's empowerment status were correlated with the error term (Wooldridge, 2002). For instance women's unobserved farm managerial ability and attitude towards risk may influence her empowerment. Endogeneity could also possibly result from bi-directional connection between food insecurity and women's empowerment. Empowered women may allocate more resources to improve farm productivity; and again, increase in farm production may result in more income and empowerment for women (Diiro et al., 2018).

Unobserved heterogeneity occurs if non-linear interaction between women's empowerment variables and unobserved factors cause the effect of women's empowerment on food insecurity to vary by individual households (Wooldridge, 2002). For example, unobserved heterogeneity in social division of class may influence differences in farming decisions. Similarly, women who are food secure have a bigger prospect of participating in community leadership activities than their food insecure counterparts (Diiro et al., 2018). By treating women empowerment score as endogenous, we apply instrumental variable estimation technique by specifying the model as:

$$F_i = \alpha + \beta_1 Empowerment_i + \beta_2 I_{1i} + \beta_3 A_{1i} + \varepsilon_i \tag{4.11}$$

$$Empowerment_i = \alpha + \lambda I_{2i} + \delta A_{2i} + \pi Z_i + \mu_i \tag{4.12}$$

In the reduced form equation (4.13), Z_i is the instrument, λ , δ and π are unknown parameters to be estimated and μ_i is the normally distributed error term.

Instruments used by earlier studies to resolve identification issue of the empowerment variable include: the variance in age or education between the male head of household and his spouse; whether households received credit from any informal sources in their community; a dummy indicating whether a woman paid any contribution or participated in community development projects in the previous year (Sraboni et al., 2014). Others include: assets or inherited land brought into the marital union by a women and the period of residency in the village (Diiro et al., 2018). In this study, a dummy indicating a woman's monetary or time contribution to any community activity in the previous year is used as exclusion restrictions for identification of our IV model. As indicated by Sraboni et al., (2014), a woman who participates in community activities is more likely to gain knowledge and self-confidence which increases her bargaining power in decision making. Participation in community activities does not however influence her food security status.

Previous research (Malapit et al., 2013; Sraboni et al., 2014: Malapit and Quisumbing, 2015) treated women's empowerment score as continuous. As such, two stage least square (2SLS) IV estimator was used. The empowerment variable is however non-linear hence 2SLS estimator may not be appropriate since it does not make distinction among discrete, continuous, or some mixture of variables. This study therefore ensured that the women's empowerment score remained within the unit interval $0 \le E \le 1$ by obtaining a fractional probit transformation of equation (4.13) as suggested by Papke and Wooldridge (1996). The transformed model was consistently estimated by Quasi-maximum likelihood estimator. The first stage transformed model can be written as:

$$E(Empowerment_i \mid X_i) = G(X_i \beta) \;= 1[\pi X_i + \lambda Z + \varepsilon_i \ge 0] \qquad (4.13)$$

Where $G(.)$ is the cumulative distribution function, that ensures the predicted values of empowerment lies within the interval (0, 1), X is a composition of exogenous variables, Z is the instrument π and λ are parameters to be estimated and ε is the error term that is normally distribution.

Given the non-linear nature of the empowerment variable, we estimated the food security equation using control function approach (CF) which has been widely used in non-linear estimations with endogenous variables (Wooldridge, 2002). According to Wooldridge, (2005), control function approach can be easily extended to fractional responses. The CF approach was implemented in three steps to account for both endogeneity and unobserved heterogeneity. At the initial stage, women's empowerment was predicted using the instrument. This followed the second stage where generalized residuals (V) obtained from the first stage estimation was added to the food insecurity equation (4.11) as an additional explanatory variable to test and control for endogeneity. These sequential steps constitute the two-stage residual inclusion (2SRI) estimation method (Terza et al. 2008) written as:

$$F_i = \alpha + \beta_1 Empowerment_i + \beta_2 I_{1i} + \beta_3 A_{1i} + \beta_4 V_i + \varepsilon_i \qquad (4.14)$$

Where F is food insecurity score. In the third step, the generalized residual from the reduced form equation was interacted with the endogenous women empowerment variable ($E_i \times V_i$) and also included in equation (4.15) as an additional variable to test and control for unobserved heterogeneity. The resulting equation to be estimated is specified as:

$$F_i = \alpha + \beta_1 Empowerment_i + \beta_2 I_{1i} + \beta_3 A_{1i} + \beta_4 V_i + \beta_5 (E_i \times V_i) + \varepsilon_i \qquad (4.15)$$

Equation (4.16) is the control function approach (Petrin and Train, 2009; Card, 2001). The variables V and $E_i \times V_i$ are control function variables which control for unobserved factors and non-linear interactions correlated with the empowerment variable. These controls allow our empowerment variable to be treated as exogenous.

In addition to equation (4.15), we investigated the pathway through which women's empowerment influence food security by analyzing production decisions, asset ownership, income decisions, credit decisions and active group member. Unlike the women's empowerment score which is a fractional component of the various indicators, the individual indicators have a continuous distribution, thus, standard instrumental variable technique is more appropriate to estimate the effect of the disaggregated indicators on food security. Previous studies showed that instruments used for the disaggregated women's empowerment variables varied. This perhaps is an indication that the same instrument may not be relevant for all the individual empowerment variables. See for instance use of different instruments for different outcome variables by Diiro et al., (2018).

Although we acknowledged potential endogeneity of the disaggregated women's empowerment variables, the lack of instruments used by previous studies limit the use of conventional instrumental variable technique. The difference in education or age of the husband and spouse could not be used because only the 5DE for women was computed. Consequently, the study adopted an alternative method of identification that exploits model heteroscedasticity to construct instruments from available regressors (Lewbel, 2007). The reduced form model to identify the effect of individual women's empowerment indicator is specified as:

$$Empowerment_{ji} = \beta X_i + \upsilon_i \qquad (4.16)$$

Equation 4.17 is similar to equation (4.13) but without external instrument. The main appeal of this method is that unlike the standard IV estimation that imposes exclusion restriction, Lewbel's approach achieves model identification without imposing any exclusion restrictions.

Identification can be achieved if there is a vector of exogenous variables N that can be either equal to X or a subset of X and the errors are heteroskedastic. The method proceeds in two steps analogous to 2SLS. In the first step, $\hat{\beta}$ is obtained from ordinary least square estimation of the women's empowerment variable on other control variables. Predicted residual $\hat{\upsilon}_i = Empowerment_i - X_i^{'}\beta$ is then obtained from the axillary equation: Instruments are generated as stated below.

$$N_i = [X_i - E(X_i)] * \hat{\upsilon}_i \tag{4.17}$$

where N is the instrument that could be equal to X or a sub-set of X, X_i are control variables $E(X_i)$ is the mean of X_i, $\hat{\upsilon}_i$ is predicted residuals and i denotes members of N, Lewbel (2007) shows that the parameter δ for empowerment in model (4.11) can be identified if the $\text{cov}(z, \varepsilon_i \upsilon_i) = 0$ and $\text{cov}(Z, \upsilon_i^2) \neq 0$. Generated instruments are like standard instruments such that the model can be estimated by 2SLS or GMM. According to Lewbel (2007) a Breusch-Pagan (1979) test should be conducted in the first stage to verify the existence of heteroscedasticity in the error term since the process is based on heteroscedasticity. Several studies (Klein and Vella, 2010; Emran et al., 2014; Hoang et al., 2014; Le moglie et al., 2015) among others have exploited heteroscedasticity for identification.

ii) Food (in)security categories and women's empowerment

Consider the households self-reported food security F_i below:

$$F_i = \begin{cases} 1 \; if \;\; food \;\; secure \\ 2 \; if \;\; moderately \; food \;\; insecure \\ 3 \; if \;\; severely \; food \;\; insecure \end{cases} \tag{4.18}$$

we let F_i to be generated by a latent variable F_i^* that takes the form of a regression structure following Greene and Hensher, (2010) as follow:

$$F_i^* = X_{1i}\beta + \delta E_i + \varepsilon_{1i} \tag{4.19}$$

Where F_i^* denotes latent food insecurity, X_i is a row vector containing individual and household variables E_i is women empowerment score for each woman, β and δ are unknown parameters to be estimated, ε_{1i} represent the error tern that is assumed to be normally distributed and i denotes an individual household. Let $u_1 < u_2 < u_3$ be the unknown threshold parameters which would also be estimated. The ordered probit model with latent food insecurity is specified as:

$$F_i = \begin{cases} 1 \; if \;\; F_i^* \le u_1 \\ 2 \; if \;\; u_1 < F_i^* \le u_2 \\ 3 \; if \;\; F_i^* > u_2 \end{cases} \tag{4.20}$$

Since F_i^* is a latent construct, the likelihood function to estimate model parameters for each food security outcome is given as:

$$P(F_i = 1) = \Phi(u_1 - X_i\beta) \tag{4.21}$$

$$P(F_i = 2) = \Phi(u_2 - X_i\beta) - (u_1 - X_i\beta)$$

$$P(F_i = 3) = 1 - \Phi(u_2 - X_i\beta) \tag{4.22}$$

For the probabilities above, the corresponding marginal effects of the changes in household food insecurity are:

$$\frac{\partial prob(F_i = 1 \mid X)}{\partial X} = -\phi(X_i\beta)\beta \tag{4.23}$$

$$\frac{\partial prob(F_i = 2 \mid X)}{\partial X} = [\phi(u_1 - X_i\beta) - \phi(u_2 - X_i\beta)]\beta \tag{4.24}$$

$$\frac{\partial prob(F_i = 3 \mid X)}{\partial X} = \phi(u_2 - X_i\beta)\beta \tag{4.25}$$

The expressions $\phi(.)$, symbolizes the probability density function.

As discussed earlier, estimating equation (4.21) by maximum likelihood (ML) produces estimates of β that are biased. One way of correcting for endogeneity requires instrumental variable modelling. We therefore modified the ordered probit model by incorporating the underlying structure of the endogenous variable. The new model with both the structural equation (4.19) and reduced form equations (4.20) are specified as follows:

$$F_i^* = \delta E_i + \beta_1 X_{1i} + \varepsilon_{1i} \tag{4.26}$$

$$E_i = \alpha + \beta_2 X_{2i} + \beta_3 Z_i + \varepsilon_{2i} \quad (4.27)$$

Where α is the coefficient of the reduced form equation and Z_i is an instrument that is relevant such that. $E(\varepsilon_i Z_i \mid X_i = 0),$ and $E(\varepsilon_i Z_i \neq 0)$ (Greene, 2012).

Rivers and Vuong (1989) suggested that the system of equations can be estimated separately or jointly using Full Information Maximum Likelihood (FIML). The later method is more efficient since it integrate the full covariance structure of the model. However, fitting FIML can be complicated and computationally demanding especially ordered choice models (Roodman, 2009). The computational difficulties of implementing the FIML is however relaxed now by conditional mixed process (cmp) proposed by Roodman (2009), which allows for the estimation of simultaneous equations with correlated errors according to the same underlying process of seemingly unrelated regression.

Definition of variables

Dependent variables

The key dependent variable of interest in this study is HFIAS (see equations 4.15 and 4.16. In these equations, it is measured as a continuous variable, but as a categorical variable in equation 4.27. It captures household food insecurity prevalence. Households are ranked into food secure, moderately food insecure and severely food insecure categories.

Independent variables

Women's empowerment in agriculture variables are defined according to A-WEAI (Alkire et al., 2013: Malapit et al., 2015). Women's empowerment score is a fractional variable that is bounded between zero and one. It is an aggregate of other A-WEAI indicators computation as described above with components indicators in Table 1.

Input in production decision captures the total number of decisions a woman makes about production. It is expected that women's sole or joint decision on production would reduce household food insecurity.

Ownership of assets captures women assets ownership and control: We expected that the greater decision making power the woman has over resources, the more food secure the household (Sraboni et al., 2014; Diiro et al., 2018).

Access to and control over credit decision measures woman's access to credit and decision making on its usage. The woman's access to and involvement in decision making about credit enhances the woman's capability to procure resources that improves productivity and yield thus reducing food insecurity (Sraboni et al., 2014; Malapit and Quisumbing, 2015).

Control over income measures how involved the woman is in household decision making on income use. We expect that women's control over the use of income and expenditure from food and cash-crop farming, livestock rearing and fisheries will motivate them to allocate more time and resources to production; thus, reducing household food insecurity (Diiro et al., 2018).

Group membership captures the number of groups in which a woman is an active member. Social group membership serves as a means of social capital and networking where members get information about farm inputs, new technology and other benefits from the community. Hence, we expect group membership to reduce household food insecurity (Sraboni et al., 2014).

Age measured in years, is a continuous variable that captures experience in farming. Most subsistence agriculture is labor intensive as such aging reduces the potential to participate in those activities. We therefore expect that aging of the farmer increases household food insecurity Kabuga et al., (2014).

Education is as a continuous variable measured in years. It influences food security through the acquisition of production information leading to better decision making on input use and production. Hence we expect education to reduce food insecurity (Kabuga et al., 2014; Murendo and Wollni, 2016).

Household size is the number of persons in the household. The variable is treated as continuous. Labor is an essential factor of production especially in smallholder farming; thus large household size imply more farm labor and lower food insecurity. On the other hand, a large household size increases the number of consumers thus putting pressure on household food consumption leading to food insecurity. The sign can therefore not be determined a priori.

Marital status is a dummy coded as one if the woman is married or else zero. With the presence of a partner, we expect food insecurity to be lower because both parties could pool family resources (Kabuga et al., 2014).

Main occupation is a binary with one donating farming as the main occupation of the woman if not zero. We expect that farming being the principal occupation, improves farm performance through greater attention to production activities and inspiration for improvement. Hence, we expect food insecurity to be lower (Meraner et al., 2015).

Plot size is a continuous variable that captures household asset endowment. It is expected that households with more land size are able to diversify their crop portfolio and cultivate more food while households with inadequate land are expected to be food insecure (Kassie et al., 2014; Murendo and Wollni, 2016).

Livestock ownership is measured using Total Livestock Unit (TLU) measure. Livestock serves as a source of food for family, income to purchase food through sale of the animals during shocks. It is expected to reduce food insecurity (Murendo and Wollni, 2016).

Plot intercropping is a dummy that captures the efficient use of available land in a complimentary manner. Food insecurity is expected to decline if two or more crops are grown on the same plot. It is coded as one if intercropping and zero otherwise (Diiro et al., 2018).

Adequate extension advice is a dummy that captures the quality of extension services provided to farmers on input use, farm management practices and on technology adoption. It takes the value one if the farmer received quality extension services and zero otherwise. Adequate extension services are therefore expected to reduce food insecurity (Diiro et al., 2018).

Adopt improved seed variety is a binary variable equal one if the farmer adopted improved seed varieties and zero otherwise. Adoption of improved seed variety increases the propensity of greater yield per hectare which reduces household food insecurity (Seymour et al., 2016).

Adoption of soil conservation technologies (SCT) enhances soil fertility, productivity and crop yield which help in achieving food security. The variable is captured as a dummy, coded as one if the farmer adopted soil conservation and zero otherwise (Wambua, 2008).

Soil type captures farmer's perception about the soil quality. Fertile soil are expected to increase yield and reduced household food insecurity while poor soil begets poor yield and increases food insecurity, other factors held constant. Soil type is categorized into fertile, medium and low quality with medium quality serving as the base category (Kassie et al., 2014).

*Soil depth*s captures farmer's perception of the depth of the soil used for cultivation. Soil depth is important for maximizing the potential of plant height, thus, shallow soil will produce poor yield and increase food insecurity, while deep soil is expected to lower food insecurity. It is categorized into deep, shallow and medium depths, with medium serving as reference (Kassie et al., 2014).

Region is a dummy variable included to control for location-specific effects such as culture and other unobserved features. The dummy variable for region equals 1 if the individual lived in Western region and 0 if they lived in Eastern region.

4.3.3 Data and descriptive statistics

This essay used household data collected by the Adoption Pathways Project (APP) between September-November 2013 before the long rain maize-legume harvesting and threshing season. About 540 household were surveyed from three counties in Eastern Kenya (Tharaka Nithi, Embu, and Meru) and two counties in Western Kenya (Bungoma and Siaya). The respondents were the principal male and female household members responsible for the welfare of the household. The study however utilized data for 260 principal females who were living in households with a principal male respondent and had information on all women's empowerment variables. In the survey areas, other crops like banana, sweet potatoes and coffee are grown along maize and legumes. Table 4.2 presents summary statistics of variables used for analysis.

The household self-rated food insecurity profile showed that about 32 percent of households perceived themselves as severely food insecure, 20 percent reported to be food secure and 48 percent marginally food insecure. The women's empowerment score showed that on average, 67 percent of women achieved adequacy in the weighted indicators. The disaggregated indicators pointed out that on average, women participated in 55 percent of decisions on production and had control over 26 percent of household assets. On average, women participated in 37 percent of income and 21 percent of credit decisions. They were active members of 39 percent of groups in their communities. Based on the adjusted A-WEAI cut-off of 80 percent threshold, the disempowerment intensity in figure 1, reveals that the most severe constraint to empowerment was women's access to and decisions on credit is. In addition to credit, other domains in which women are disempowered are women's control over use of income and assets ownership. The disempowerment of women in these domains is evidence of gender inequalities in agriculture as iterated by Fisher and Qaim (2012). Conversely, women were observed to be empowered in group membership and production decision making.

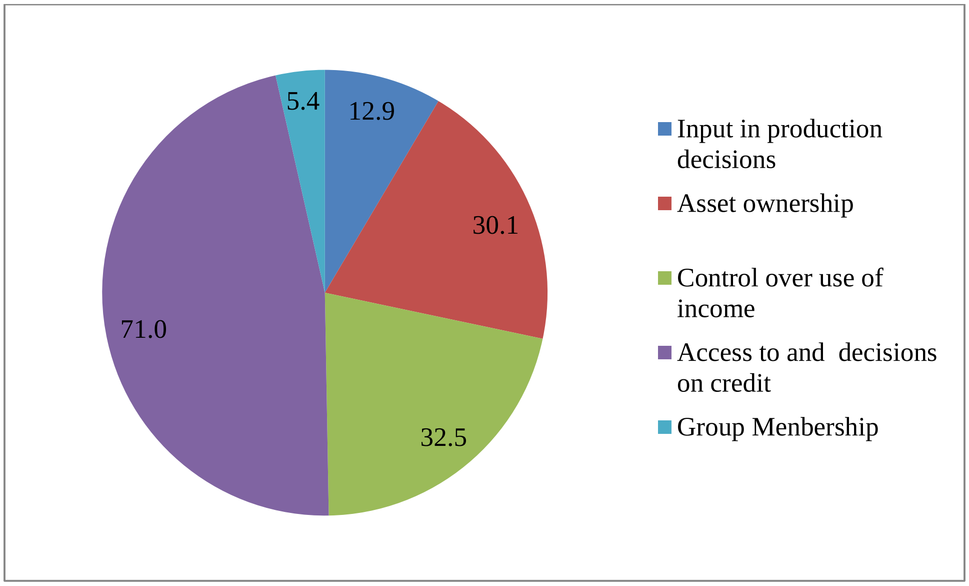
Women in the sample were about 48 years old and had attained approximately 7 years of education. The mean number of persons per household was 5. Majority of the women were farmers, married and about 30 percent of them were plot managers. Households owned on average 1.3 ha of land and at least 2 units of livestock. Majority of the plots were intercropped and about 37 percent of farmers reported receiving adequate extension services. Few farmers adopted improved seed varieties as well as soil conservation technology. About 40 percent of households perceived their plot as having fertile and deep soil while few reported poor and shallow soil. About 41 percent of our sample was from Western region. Finally, 51 percent of women reported participating in community activities in the previous year.

Table 4.2: Descriptive Statistics of Variables Included in the Household Food Insecurity Model

Variable	Mean	. Std. Dev.	Min	Max
Outcome Variables				
Food Secure (yes=1)	0.20	0.42	0	1
Moderately Food Insecure (yes=1)	0.48	0.50	0	1
Severely Food Insecure (yes=1)	0.32	0.46	0	1
Women's Empowerment Indicators				
Women's Empowerment Score	0.67	0.47	0	1
Number of production decisions in which woman participated	2.20	0.74	0	4
Number of assets woman has control over	3.14	0.16	0	12
Number of income decisions in which the woman participated	1.93	1.44	0	5
Number of credit decisions in which the woman participated	1.47	0.98	0	7
Number of formal and informal group membership	2.33	1.13	0	6
Individual and Household Characteristics				
Age of the woman (years)	48.19	14.98	21	94
Educational attainment (years)	6.59	3.67	0	15
Household size (number of persons)	5.24	2.85	1	17
Marital Status (Married=1)	0.59	0.49	0	1
Main occupation (agriculture=1)	0.85	0.36	0	1
Plot size (ha)	1.38	1.97	0.1	25
Livestock ownership (TLU)	1.96	0.41	0	1.9
Plot manager (yes=1)	0.31	0.27	0	1
Agricultural activities and plot attributes				
Received adequate extension advice (yes=1)	0.37	0.48	0	1
Plot intercropped (yes=1)	0.65	0.34	0	1
Adopted improved seed variety (yes=1	0.28	0.25	0	1
Adopted soil conservation	0.36	0.25	0	1
Soil type (medium soil=base)				
Fertile soil (yes=1)	0.45	0.36	0	1
Poor soil (yes=1)	0.15	0.33	0	1
Soil depth (medium depth=base)				
Deep soil (yes=1)	0.42	0.28	0	1
Shallow soil (yes=1)	0.20	0.45	0	1
Whether woman has participated in any community activity*in the previous year (yes=1)	0.51	0.50	0	1
Regional Dummy				
Region (Western =1; Eastern=0)	0.41	0.49	0	1

***i**nstrument

Figure 4.1: Percentage of women with inadequacy in various indicators



4.4 Empirical results and discussion

4.4.1 Section overview

This section presents empirical results and discussions of the effect of women's empowerment on household food insecurity. Analysis of the association between household food insecurity and women's empowerment was articulated in two parts. The first part examined the effect on the aggregate food security index and the second on the food insecurity categories. Econometric estimation began with the regression specification error test (RESET) to verify the functional form of our first stage regression model. The Ramsey reset F-test for the joint null hypothesis that the regression model had a linear form was rejected at 5 percent significance level. Consequently, the two stage estimation of the fractional probit model and the two stage least square commenced with the linear prediction of the empowerment score on all control variables and the instrument.

Table 4.3 presents regression results of first stage estimation for the fractional probit model and the two-stage least square used as a diagnostic tool for assessing the strength of identification of our instrument. The endogeneity test rejects the null hypothesis that our women's empowerment variable is exogenous. The Kleibergen and Paap (2006) rank statistic also showed that our instrument is relevant. Our F statistics which coincides with the Cragg-Donald wald F-statistics in the just identified model rejects the null hypothesis that our model is weakly identified.

Marginal effects from the first stage regression for both the two-stage least squares and the fractional probit indicated that the number of persons in the household was positively related to women's empowerment. This is according to expectation given the labor intensive nature of smallholder agriculture. An additional adult household member in a farm household implies more household labor and thus more output and income. As expected, livestock ownership had a positive and significant effect on women's empowerment. This suggests that interventions aimed at empowering women should consider including livestock in their portfolio. The result agrees with review from Meinzen-Dick et al., (2011) which shows that livestock ownership by women not only empowers them but enhances household food security.

The result also indicated that being a female plot manager increased women's empowerment. Diiro et al., (2018) indicated that female managed plots tend to be less fertile and had fewer labor inputs compared to plots owned by male farmers. This shows that closing the gender gap requires measures that will ensure female plot managers receive services and inputs as their male counterparts. Analysis from the 2SLS revealed that intercropping disempowered women. This finding was unexpected. The effect was however not different from zero from the fractional probit marginal effect. As expected, adopting improved seed varieties increased the probability of being empowerment while having a plot with shallow soil disempowered women. The result also indicates that women in the Western region were less disempowered compared to those in the Eastern region.

Table 4.3: First Stage Regression Results for Women's Empowerment Score

Variables	2SLS Coef.	2SLS Std. Err.	Fractional Probit Coef.	Fractional Probit Std. Err.
Age (years)	0.0003	0.0009	0.0004	0.0008
Education (years)	0.0007	0.0035	0.0007	0.0034
Household size(no. of persons)	0.0088**	0.0041	0.0082**	0.0040
Marital status (Married=1)	0.0197	0.0258	0.0210	0.0248
Main occupation (agriculture=1)	0.0076	0.0353	0.0055	0.0323
Plot size (ha)	0.0016	0.0042	0.0017	0.0046
Livestock ownership (TLU)	0.0723***	0.0272	0.0736***	0.0271
Plot manager (yes=1)	0.2160***	0.0553	0.2028***	0.0482
Received adequate extension advice (yes=1)	0.0314	0.0240	0.0270	0.0234
Intercropped (yes=1)	-0.0601*	0.0359	-0.0539	0.0340
Adopted improved seed varieties (yes=1)	0.1632***	0.0494	0.1635***	0.0490
Adopted SCT (yes=1)	0.0642	0.0497	0.0612	0.0447
Fertile soil (yes=1)	-0.0387	0.0335	-0.0385	0.0316
Poor soil (yes=1)	-0.0461	0.0430	-0.0457	0.0383
Deep soil (yes=1)	-0.0041	0.0450	0.0012	0.0443
Shallow soil (yes=1)	-0.0583**	0.0264	-0.0522**	0.0249
Region (Western =1; Eastern=0)	-0.0835***	0.0300	-0.0808***	0.0277
Instrument				
participation in any community activities in the previous year (yes=1)	0.2667***	0.0798	0.2219***	0.0585
Constant	0.2642**	0.1235		
Observations	260		260	
F(1, 241)	11.16***			
Log pseudolikelihood			-134.05	
Wald chi2(18)			90.03***	
Ramsey reset test (Ho: The regression is correctly specified)	3.48**			
IV diagnostic test				
Endogeneity test Ho: Exogenous	3.67*			
Under-identification test Ho: (unidentified) Kleinbergen-Paap rk LM statistics Chi-sq(1)	7.55***			

Robust standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1

Table 4.4 presents results from the second stage regression for the outcome model. The fractional probit two-stage residual inclusion shows estimates that control for endogeneity, the fractional probit control function model results corrected for unobserved heterogeneity while the ordinary and two-stage least squares were presented for comparison purposes. The coefficient from the women's empowerment score had the expected sign from all the approaches. The OLS results were however insignificant, while those from the 2SLS and FP-2SRI and the women's empowerment residual were significant. This shows that neglecting the issue of endogeneity yields erroneous estimates of the effect of women's empowerment on household food insecurity.

Moreover, estimated effects of women's empowerment on food insecurity from the 2SLS showed a marginal significance while the FP-2SRI revealed a highly significant effect of women's empowerment on the outcome variable. The coefficient from the women's empowerment score from the 2SLS showed that *ceteris paribus*, a 10 percent increase in women's empowerment score leads to 36 percentage points decrease in household food insecurity. On the other hand, estimates from the FP-2SLS showed 19 percentage points decrease. This suggests that functional misspecification of the first stage regression will result in biased estimates and overestimation of the true effect of women's empowerment on household food security in the second stage. The interaction term from the FP-CF was insignificant implying that unobserved heterogeneity may not be a problem in this model.

The significant effect of women's empowerment in reducing household food insecurity is in line with Malapit et al., (2013); Srabon et al., (2014); and Malapit and Quisumbing, (2015) whose findings demonstrated that women empowerment had a positive effect on food and nutrition outcomes. Result from the FP-2SRI showed that other significant determinants of household food insecurity include education, household size, plot size, soil conservation practice, fertile and deep soil as well as residence. These variables also displayed the expected signs. Holding other factors constant, an additional year of education achieved by women lowered the chance of household food insecurity by 14 percentage points. This implies that empowering women to achieve higher levels of education is essential for achieving food security. This finding supports studies from subjective food security measure (Kabuga et al., 2014; Murendo and Wollni, 2016).

For households with an average of five persons, an additional individual resulted to a 13 percentage point increase in the probability of food insecurity holding all else constant. The result further indicated that increase in the average soil fertility by 10 percentage points reduced food insecurity by the same magnitude. Similarly, increasing soil depth by one unit reduced the possibility of food insecurity by 67 percentage points. This suggests that soil fertility and depth are intrinsically linked to food security. Consistent with our expectation, adoption of soil conservation technology lowered the probability of household food insecurity. The findings imply that given the frequent occurrence of droughts and other erratic climatic conditions which leads to declining crop productivity, achieving food security requires sustainably managing the environment through various soil conservation techniques to support crop production. Similarly, a larger plot size lowered the risk of household food insecurity. This result supports earlier studies (Kassie et al., 2014; Kabuga et al., 2014) that found land size to significantly influence household food security.

The consistent significant influence of women's empowerment in reducing food insecurity from both the 2SLS and FP-2SRI suggest that improving women's empowerment is a strategic way of reducing food insecurity in Kenya. Moreover, an important take-away form this analysis is that functional form misspecification of the empowerment variable and failure to control for potential endogeneity produces incorrect estimates of its effect on food security.

Table 4.4: The Effect of Women's Empowerment on Household Food Insecurity

Variables	OLS	2SLS	FP-2SRI[1]	FP-CF[2]
Empower score	-1.204	-3.611*	-1.852**	-3.225
	(0.749)	(1.883)	(0.789)	(2.261)
Empowerment residual			0.432**	1.640
			(0.211)	(1.759)
Interaction of empowerment score and empowerment residual				-1.267
				(1.800)
Age (years)	-0.006	-0.006	-0.005	-0.005
	(0.010)	(0.010)	(0.011)	(0.010)
Education (years)	-0.141***	-0.135***	-0.140***	-0.136***
	(0.038)	(0.039)	(0.036)	(0.037)
Household size (no. of (persons)	0.108**	0.135**	0.125***	0.133**
	(0.048)	(0.045)	(0.050)	(0.053)
Marital status (Married=1)	-0.211	-0.155	-0.217	-0.213
	(0.293)	(0.299)	(0.310)	(0.330)
Main occupation (agriculture=1)	-0.330	-0.271	-0.322	-0.285
	(0.375)	(0.367)	(0.374)	(0.387)
Plot size (ha)	-0.102**	-0.096**	-0.092*	-0.091
	(0.043)	(0.045)	(0.065)	(0.061)
Livestock ownership (TLU)	0.281	-0.126	-0.174	-0.157
	(0.277)	(0.289)	(0.263)	(0.316)
Plot manager (yes=1)	-0.095	0.403	0.134	0.246
	(0.551)	(0.622)	(0.579)	(0.620)
Received adequate extension advice (yes=1)	0.259	0.362	0.345	0.378
	(0.266)	(0.278)	(0.274)	(0.251)
Intercropped (yes=1)	-0.390	-0.278	-0.374	-0.342
	(0.401)	(0.402)	(0.375)	(0.401)
Adopted improved seed varieties (yes=1)	-0.170	-0.164	-0.085	-0.026
	(0.576)	(0.664)	(0.521)	(0.601)
Adopted SCT (yes=1)	-1.081**	-0.948*	-1.006*	-1.000**
	(0.549)	(0.547)	(0.528)	(0.464)
Fertile soil (yes=1)	-0.993***	-1.132***	-1.083***	-1.113***
	(0.310)	(0.324)	(0.332)	(0.303)
Poor soil (yes=1)	0.310	0.161	0.206	0.172
	(0.395)	(0.389)	(0.419)	(0.407)
Deep soil (yes=1)	-0.619*	-0.634*	-0.674*	-0.692**
	(0.365)	(0.370)	(0.353)	(0.369)
Shallow soil (yes=1)	-0.415	-0.568*	-0.549*	-0.594*
	(0.308)	(0.321)	(0.289)	(0.331)
Region (Western =1; Eastern=0)	-0.691*	-0.876**	-0.705*	-0.740*
	(0.347)	(0.382)	(0.351)	(0.372)

Variables	OLS	2SLS	FP-2SRI[1]	FP-CF[2]
Constant	3.488***	4.705***	4.078***	5.308**
	(1.148)	(1.353)	(1.227)	(2.265)
Observations	260	260	260	260
R-squared	0.246	0.206	0.259	0.261

Note Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 for OLS and 2sls
[1] Fractional probit two-stage residual inclusion
[2] Fractional probit control function
Bootstrap standard error for FP-2SRI and FP-CF

We further assessed how each indicator of the women's empowerment score individually affects household food insecurity. The analysis deviated from conventional two-stage least square instrumental variable estimation of continuous variables due to the lack of relevant instruments. As a result, the Lewbel (2007) estimation procedure was adopted for assets, income, credit and group membership indicators. Since our instrument proved to be relevant for production decisions indicator, we used the IV GMM estimator which is robust to heteroscedasticity (Baum et al., 2003). Table 4.5 presents results from analysis and IV diagnostic statistics. The test of endogeneity from the first stage rejected the null hypothesis of exogeneity for all women's empowerment indicators. The Breusch-Pagan/Cook-Weisberg test for heteroscedasticity from the first stage regression which serves as a necessary condition for the Lewbel's two-stage estimator rejects the null hypothesis of constant variance for all indicators. Moreover, the Kleibergen-Paap rk Wald statistic showed that our models were identified.

Result from IVGMM in Table 4.5 indicates that women's participation is production decision variable was negative and significantly associated with household food insecurity. Clearly, a 10 percentage point increase in the number of decisions women make on production led to 23 percentage point decrease in household food insecurity. Evidence from figure 1 supports this findings that the lower the disempowerment of women in decision making on production, the greater the effect on food security. This suggests the importance of empowering women to participate in farm input and out-put decision making. This finding agrees with previous work in Bangladesh that showed a positive correlation between women's decision making on production and dietary intake (Malapit and Quisumbing, 2014).

Result further showed that women's asset ownership had a greater effect in reducing food insecurity. Increment in women's asset ownership by 10 percent lowered the probability of food insecurity by 56 percent. Again, linking this finding to figure 1 reiterates the argument for women's empowerment in assets ownership. Sraboni et al., (2014) found significant effect of women's asset ownership on food and nutrition security in Bangladesh but found no significant effect for production indication. Enhancing women's autonomy to make production decisions also had the propensity of reducing household food insecurity. Specifically, an additional decision women made about production lowered the odds of household food insecurity by about 2.3 percentage points. The finding is in line with the study by Diiro et al., (2018) on Kenya, which showed that women's empowerment in production decision making improved agricultural productivity and Seymour et al., (2016) who found that women's asset ownership and decision making over production were the most important women's empowerment indicators that influenced improved maize variety adoption in Kenya and hence food security.

Women's autonomy in making decisions on production and the ownership of assets enables them to make optimal decisions on crop types to produce and to allocate resources efficiently which could improve production and food security. Women's access to and decision making on credit ensure higher agricultural productivity. However, this variable had no significant effect on the probability of reducing food insecurity. Similarly, the participation of women in making decisions on income and their membership to various community groups did not significantly reduce the probability of food insecurity. This could probably be explained by the high percentage of women who were disempowered in those domains as shown in figure 1.

Other variables that significantly influenced food security include: education, household size, plot size, adoption of soil conservation technology, fertile soil, deep and shallow plot depth as well as regional dummy. The regional dummy was also significant for estimates with assets and income indicators only. On the overall, results from other controls mirror previous findings.

Table 4.5: Effects of Women's Empowerment Indicators on Household Food Insecurity

Variables	IVGmm	Lewbel (2007) Two-stage estimator			
Production decision	-2.266*				
	(1.285)				
Asset ownership		-5.601***			
		(1.743)			
Income decisions			-0.070		
			(0.138)		
Credit decisions				-0.086	
				(0.172)	
Group membership					-0. 096
					(0.188)
Age (years)	0.009	0.009	-0.011	-0.012	-0.005
	(0.015)	(0.010)	(0.010)	(0.010)	(0.010)
Education (years)	-0.079	-0.068***	-0.155***	-0.168***	-0.160***
	(0.061)	(0.043)	(0.035)	(0.035)	(0.038)
HH size (no. of persons)	0.155**	0.139***	0.103**	-0.249**	0.115**
	(0.068)	(0.045)	(0.043)	(0.044)	(0.043)
Married(yes=1)	-0.190	-0.004	-0.249	-0.359	-0.403*
	(0.337)	(0.263)	(0.268)	(0.273)	(0.270)
Main occupation. agriculture(yes=1)	0.312	-0.571	-0.266	-0.505	-0.559
	(0.555)	(0.361)	(0.344)	(0.359)	(0.358)
Plot size (ha)	-0.060	-0.110***	-0.107***	-0.075**	-0.120***
	(0.066)	(0.042)	(0.039)	(0.040)	(0.036)
Livestock ownership (yes=1)	0.028	0.129	-0.317	-0.300	-0.347
	(0.404)	(0.309)	(0.268)	(0.258)	(0.255)
Plot manager (yes=1)	1.377	0.080	-0.296	-0.322	-0.594
	(1.116)	(0.494)	(0.476)	(0.451)	(0.481)
Received adequate extension advice (yes=1)	0.181	0.062	0.154	0.054	0.246
	(0.298)	(0.237)	(0.247)	(0.238)	(0.251)
Intercropped (yes=1)	-0.697	0.560	0.347	0.412	0.568
	(0.804)	(0.390)	(0.395)	(0.374)	(0.375)
Adopted Improved	0.726	-0.349	-0.220	-0.348	-0.220
Variety (yes=1)	(0.836)	(0.536)	(0.503)	(0.501)	(0.494)
Adopted SCT (yes=1)	-0.887	-1.045*	-1.116**	-1.124**	-1.283**
	(0.604)	(0.514)	(0.510)	(0.512)	(0.513)
Fertile soil (yes=1)	-0.912**	-0.590*	-0.894***	-1.022***	-1.005***
	(0.376)	(0.310)	(0.292)	(0.290)	(0.287)
Poor soil (yes=1)	0.509	0.111	0.367	0.341	0.315
	(0.411)	(0.362)	(0.367)	(0.372)	(0.379)
Deep plot depth (yes=1)	-1.307**	-0.449	-0.536*	-0.507*	-0.625*

Variables	IVGmm	Lewbel (2007) Two-stage estimator			
	(0.592)	(0.339)	(0.336)	(0.340)	(0.339)
Shallow plot depth (yes=1)	-0.616*	-0.171	-0.373	-0.495	-0.179
	(0.385)	(0.266)	(0.286)	(0.288)	(0.275)
Eastern (yes=1:	-0.157	-0.693*	-0.732**	-0.524	-0.490
Western=0)	(0.480)	(0.322)	(0.301)	(0.317)	(0.316)
Constant	4.933***	3.186***	3.269***	3.491***	2.938***
	(1.618)	(1.040)	(1.246)	(1.044)	(1.016)
Observations	260	260	260	260	260
test for hetero (Breusch-Pagan) Ho: constant variance chi2(1)		5.07**	9.14**	8.89**	9.24**
F(17, 224)	4.97**	2.49***	7.01**	11.41***	5.2***
Endogeneity test Ho: Exogenous Chi-sq(1)	11.90*	13.19**	12.11**	11.21*	15.36**
Under-identification test (Kleibergen-Paap rk Wald statistic) Ho: Under-identified Chi-sq(17)	3.92**	48.99***	137.7***	224.2***	102.13***

Robust standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1

To complement results from the food insecurity score in Table 4.4, we investigated how a change in women's empowerment could affect food insecurity prevalence across categories. Table A12 in appendix 3 present full model parameters of maximum likelihood estimates obtained from the IV ordered probit bivariate simultaneous equation. The significant "atanhrho" statistics is an indication that the null hypothesis of exogeneity of the women's empowerment score is rejected. Thus, necessitating the use of an ordered IV estimator rather than the single equation ordered probit model estimator.

The marginal effects from the IV ordered probit regression are presented in Table 4.6. Both the food secure and severely food insecure groups have significant coefficients while the moderately food insecure category has no significant coefficients. This could be explained by the single crossing property which is a feature of single index function models like the ordered probit (Boes and Winkelmann, 2006). An illustration of single crossing in our results can be traced from the maximum likelihood estimates in Table A3. Since the partial derivatives change sign exactly once in a sequence from 0-j categories, the negative coefficient on our women's empowerment variable changes sign once from negative to positive values in the first category and then to negative value in the last category. This issue however does not significantly affect our results.

The result indicated that women empowerment increased the prospect of household being food secure while the likelihood of household severe food insecurity decreased. This result is analogous with earlier results even with new measurement of food security. This evidently suggests that women's empowerment plays a pivotal role in the achievement of food security. This analysis however showed clearer pattern in the magnitude of the effect. An improvement in women's empowerment increased the prospect of food security by 75 percentage points and decreased the odds of being food insecure by 81 percentage points. The effect of women's empowerment in reducing food security was 7.6 percentage points larger in magnitude than the probability of increasing food security. This suggests that any action taken towards improving women's empowerment will generate significant impact in reducing food insecurity. Ceteris paribus, increase in the level of education, plot size, soil fertility and plot depth increases the probability of household food security and reduces the risk of severe food insecurity. On the overall, results from the IV ordered probit provides support to earlier findings from our fractional probit 2SRI estimates on the aggregate food insecurity index in Table 4.3.

Table 4.6: Marginal Effects of IV-Ordered Probit for Women's Empowerment and HFIAP

Variables	Food Secure	Moderately Food Insecure	Severely Food Insecure
Empowerment score	0.7522***	0.0570	-0.8092***
	(0.2309)	(0.0538)	(0.2127)
Age (years)	0.0010	0.0001	-0.0011
	(0.0016)	(0.0001)	(0.0017)
Education (years)	0.0169***	0.0013	-0.0182***
	(0.0065)	(0.0015)	(0.0072)
Household size(no. of persons)	-0.0173**	-0.0013	0.0186**
	(0.0073)	(0.0014)	(0.0076)
Marital status (Married=1)	0.0145	0.0011	-0.0156
	(0.0466)	(0.0039)	(0.0503)
Main occupation (agriculture=1)	0.0071	0.0005	-0.0077
	(0.0536)	(0.0041)	(0.0577)
Plot size (ha)	0.0191**	0.0014	-0.0205*
	(0.0097)	(0.0018)	(0.0107)
Livestock ownership (TLU	-0.0337	-0.0026	0.0362
	(0.0492)	(0.0043)	(0.0525)
Plot manager (yes=1)	-0.0973	-0.0074	0.1046
	(0.0927)	(0.0091)	(0.0976)
Received extension services (yes=1)	-0.0196	-0.0015	0.0211
	(0.0411)	(0.0035)	(0.0442)
Intercropped (yes=1)	-0.0503	-0.0038	0.0541
	(0.0648)	(0.0066)	(0.0700)
Adopted improved variety (yes=1)	-0.0289	-0.0022	0.0311
	(0.0934)	(0.0068)	(0.0998)
Adopted SCT (yes=1)	-0.0135	-0.0010	0.0146
	(0.0821)	(0.0063)	(0.0883)
Fertile soil (yes=1)	0.1938***	0.0147	-0.2085***
	(0.0535)	(0.0166)	(0.0590)
Poor Soil (yes=1)	0.0632	0.0048	-0.0680
	(0.0585)	(0.0071)	(0.0634)
Deep plot depth (yes=1)	0.0352*	0.0027	-0.0379*
	(0.0614)	(0.0058)	(0.0664)
Shallow plot depth (yes=1)	0.0858	0.0065	-0.0923
	(0.0509)	(0.0076)	(0.0539)
Region (Western =1; Eastern=0)	0.1057	0.0080	-0.1138
	(0.0538)	(0.0091)	(0.0569)

Robust standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1

4.5 Summary, Conclusion and Policy Implications

4.5.1 Summary

The important role of women's empowerment for food security has generated a lot of interest in identifying relevant channels of empowerment that can be used for policy intervention. The development of the women's empowerment in agriculture index has spawned research on investigating its effect on various agricultural outcomes. Previous research (Malapit et al., 2013; Srabon et al., 2014; Malapit and Quisumbing, 2015) established that women's empowerment in agriculture is significantly correlated with food security outcomes. These studies are however based on dietary diversity and other anthropometric measures that neither captures the psychological experience of those affected by food insecurity nor their risk of food insecurity. These studies have also mainly used two stage least square estimators that do not address non-linearity of the empowerment variable in the first stage. This essay adds to the literature by assessing the effect of women's empowerment on household food security using the Household Food Insecurity Access Scale (HFIAS) to measure household food insecurity. It further uses estimation techniques that simultaneously control for non-linearity and endogeneity of the empowerment variable (Terza et al., 2008: Papke and Wooldridge, 1996: Petrin and Train, 2009).

Using data collected from 540 principal male and female households in Western and Eastern Kenya, we constructed the women's empowerment score using an adjusted version of the A-WEAI methodology (Alkire et al., 2013: Malapit et al., 2015). The women's empowerment score showed that 67 percent of women achieved adequacy in the various indicators. Disempowerment statistics indicated that women were mostly disempowered in access to and control over credit, control over use of income and assets ownership. They however achieved adequacy in group membership and production decision making. The Food insecurity index was computed from data collected using Principal Component Analysis (PCA) and the Household Food Insecurity Access Prevalence (HFIAP) was constructed according to the threshold defined by the HFIAS methodology (Coates et al., 2007). The food insecurity prevalence showed that 32 percent of households were severely food insecure, 48 percent moderately food insecure and 20 percent food secure.

The general effect of women' empowerment on food insecurity index was assessed through the aggregated women's empowerment score and individual component indicators. Both fractional probit two stage residual inclusion (FP-TSRI) and control function estimation strategies were adopted. The fractional probit two stage residual inclusion controlled for potential endogeneity and non-linearity of the women's empowerment score (Terza et al., 2008: Papke and Wooldridge, 1996) while the control function approach corrected for potential unobserved heterogeneity (Petrin and Train, 2009). Exploration of the pathways through which components of women's empowerment indicators influenced food insecurity made use of IVGMM and Lewbel (2007) two-step estimators. Alternative specification to explore the influence of women's empowerment on household food security prevalence used instrumental variable ordered probit model. A dummy indicating women's financial or time contribution to community activity(s) during the previous year was used to instrument the women's empowerment score (Sraboni et al., 2014).

Our results indicate that women's empowerment is an endogenous determinant of food insecurity but individual heterogeneity bias was not an issue in our model. Rejection of the null hypothesis of first stage linear form from the regression specification error test (RESET) prompted the use of a fractional probit model. When we did not control for the endogeneity, the empowerment variable was ineffective in lowering the probability of food insecurity. And when we did not correct for non-linearity of the empowerment variable, its effect was over stated. Our main finding, after controlling for endogeneity and non-linearity of the women's empowerment score, is that, holding other factors constant, women's empowerment in agriculture has a substantial effect in reducing the probability of household food insecurity. This result is consistent with the findings of some of the studies in the literature (see, for example, Malapit et al., 2013; Srabon et al., 2014; Malapit and Quisumbing, 2015). Analysis of individual indicators showed that empowering women to make key decisions on crop production and to own assets are important channels through which women's empowerment in agriculture influence household food security.

Result further indicated that an increase in the level of education by a year reduced household food insecurity by an average of 14 percent points. Other covariates such as plot size, adoption of soil conservation technology, fertile soil and deep soil were also significant in reducing food insecurity. Conversely, larger household size worsens household food insecurity. Estimates from the regional dummy showed that compared to Eastern region, households in Western region were more likely to be food secure. This finding implies that food security is closely linked with human capital development and the environmental sustainable agriculture, thus effectively connecting and improving this link is crucial for the attainment of food security.

4.5.2 Conclusion

Based on the findings from this essay, we can draw four main conclusions. First, women's empowerment in agriculture has the potential to reduce household food insecurity (Malapit et al., 2013; Srabon et al., 2014; Malapit and Quisumbing). Second, women's empowerment is an endogenous determinant of food security. The effect of women's empowerment appears to be ineffective in influencing food security in models that do not control for this endogeneity. Attempts to investigate the effectiveness of women's empowerment outcomes must control for its endogeneity and non-linearity if they are to arrive at credible conclusions. One way of controlling for non-linearity and endogeneity is by using the Fractional-Probit Two–Stage–Residual–Inclusion method (Papke and Wooldridge 1996: Terza et al., 2008). Third, women's empowerment in production decision making and assets ownership are important pathways through which women's empowerment in agriculture can reduce household food insecurity. The availability of relevant instrument for delineating the effect of individual instruments is sometimes challenging, thus parameter identification through the exploitation of model heteroscedasticity to construct instruments from available regressors is a robust alternative (Lewbel, 2007). Finally, our findings highlight the important role of education, land size, fertile soil, deep soil and adoption of soil conservation technology in reducing food insecurity.

4.5.3 Policy implications

This essay has established that women's empowerment in agriculture plays an important role in reducing food insecurity. Specifically, women's participation in production decisions and the ownership of productive resources are pathways through which women's empowerment reduce food insecurity. This implies that policy makers should endeavor to increase the participation of women in decision and policy-making at all levels on issues that affect their lives and food security. Both national and traditional reforms that would enable women own and control productive assets are worthwhile interventions that would yield long-term dividend in food security. Also women were mostly disempowered in access to and decisions on credit. Thus policies and programs that will enable women access credit with minimal collateral requirements and moderate interest rate are recommended.

The significant correlation between women's education and household food security suggests that policy intervention on achieving food security should invest substantial resources in the promotion of rural education. The negative and significant relationship between land size and food insecurity indicates policy action should also be focused in that direction. Since productive land is scarce and expansion of cultivated plot is not feasible, sustainability in food security will entail intensive agriculture. Thus, investment in agricultural productivity through policy interventions that could help farmers acquire cheaper inputs such as fertilizers and seedlings. Also, simple production technology like crop rotation and diversification as well as more advanced interventions like irrigation and greenhouses provide an important way forward to alleviating food insecurity.

Soil attributes are important for food security, hence interventions such as agronomic soil testing and policies that could enable farmer's access affordable fertilizer to improve soil fertility of their farms are recommended. Adoption of soil conservation technology is also an important determinant of food security. Consequently, promoting the adoption of sustainable agricultural practices is imperative. This brings in the important role of agricultural extension services to strengthen the capacity of farmers in improved soil management and conservation practices like mulching, tillage, cover cropping contour and use of organic and inorganic fertilizers among others.

CHAPTER FIVE: SUMMARY, CONCLUSIONS AND POLICY IMPLICATIONS

5.1 Overview of chapter

This chapter summarizes and concludes the thesis. The next section presents a summary of the thesis. Section 5.3 presents the main conclusions of the study and highlights the contribution of the thesis. Section 5.4 presents policy implications of the study findings, while the last section presents areas for further research.

5.2 Summary

Rural poverty and food insecurity are among major development challenges faced by the Kenyan government. This has been attributed to low and declining agricultural sector growth, limited smallholder market participation, disadvantaged position of women farmers who provide the larger share of agricultural labor force, idiosyncratic weather factors among others. Amidst global competition, certification requirements coupled with market failures in input and credit markets, contract farming has been a powerful mechanism for linking farmers to market and addressing simultaneous production challenges. Both government and private sector efforts have been put in place to link smallholder farmers to formal contracts. The overarching objectives of various public development strategies such as Economic Recovery Strategy of 2003; Kenya Vision 2030 of 2008; Agricultural Sector Development Strategy 2010-2020 and Strategy for Revitalizing Agriculture have been geared towards smallholder commercialization and food security.

Despite these interventions, a large proportion of smallholder farmers in a prospective growth sector like avocado are still not linked to the global market due to non-participation in contract farming. Moreover, although evidence from gender literature speaks of changing gender roles in agricultural production, there is a dearth of evidence on how this trend manifests itself in the avocado sector. The issue of food insecurity is also a major challenge facing the Kenyan government. Some empirical studies have exploited caloric and anthropometric measures of food security to demonstrate the significant effect of women's empowerment in alleviating food insecurity. However, literature on the effect of women's empowerment on household's own assessment of food insecurity is scarce. This thesis addresses this gap through three key objectives. First, we investigate the determinants of avocado contract farming and factors that explain differentials in quality and quantities of avocados harvested and sold by contract and non-contract farmers (essay one). Second, we investigate gender patterns in labor allocation to avocado production and other economic activities (essay two), and third, we assess the effect of women's empowerment on food security in Kenya (essay three).

The first two objectives were addressed using cross sectional data collected by Productive Employment in Segmented Markets of Fresh Produce (PRESM) project from Murang'a County, Kenya. Sampled households included 266 contract farmers, 144 farmers who were newly organized into groups to sign contracts with SME (exporters) known as transition farmers and 380 farmers without contracts. Due to the similarities in characteristics between transition and non-contract farmers, the two were grouped as non-contract farmers. Analysis of the determinants of adoption of avocado contract farming was done using probit model. We further assessed the sources of gap between contract and non-contract farmers in quality and quantities of avocados harvested and sold, while controlling for selectivity bias, using the Oaxaca-Blinder decomposition model. To assess gender patterns in labor allocation to avocado production and other economic activities, we used individual level data for 1,109 adult females and 1,086 males from the same households. The double hurdle model was used to estimate participation and intensity of time use for avocado production and other economic activities. We further investigated the role of contract farming on gendered labor allocation in avocado production activities such as land preparation, weeding harvesting and marketing using the Tobit model.

The effect of women's empowerment on food security in Kenya was analyzed using data collected by the Adoption Pathways Project (APP) project in Western and Eastern Kenya from 540 households. Food security was measured using the Household Food Insecurity Access Scale (HFIAS) tool, which captures the psychological dimension of household food security (Coates et al., 2007). The effect of women's empowerment on food security was operationalized both in aggregated women's empowerment score and individual component indicators. The women's empowerment indicators were constructed following the methodology of the Abbreviated Women's Empowerment in Agriculture Index (A-WEAI) -see Alkire et al., (2013); Malapit et al., (2017). Our study focused on Five Domains of Women's Empowerment (5DE) aspect of

WEAI. We estimated a model of food security with the aggregated value of women's empowerment score that corrected for endogeneity, individual heterogeneity and non-linearity of the empowerment variable. Based on the econometric literature which shows that in the absence of relevant instruments one can use heteroscedasticity for model identification (see Lewbel, 2007), we estimated the effect of individual women's empowerment indicators on food security using heteroscedasticity-based identification.

Results for essay one showed that the age of the household head, number of *Hass* trees owned, value of total assets, access to information on avocado production and marketing, hired labor, cost of transporting avocados to market, training received in avocado agronomy and frequency of avocado meeting attendance were significant determinants of avocado contract participation. The literature (see, for example, Warning and Key 2002; Wainaina et al., 2012; Cahyadi and Waibel 2013) supports this finding. Gap analysis showed that selection bias was not an issue in our model. Results from the Oaxaca decomposition indicated that the overall gap in quantities of avocado harvested and sold by contract and non-contract farmers was mainly due to differences in endowments while the gap in the quality of avocados sold was entirely due to differences in returns to endowments.

The significant endowment effect in quantities harvested was explained by differences in the number of productive *Hass* trees owned, land size, information received on production and marketing and differences in knowledge and practice of agronomy such as rate of fertilizer and manure application and tree pruning and grafting. Similarly for quantities sold, the number of *Hass* trees owned, hired labor and information on production and marketing contributed to the endowment gap. Non-contract farmers, however had some structural advantage in terms of land owned, cost of transporting avocados to the market and frequency of avocado group meeting attendance. On the other hand, decomposition for quality of avocados sold revealed that farmer's demographic characteristics such as age, education and main occupation as well as knowledge in avocado agronomy and record keeping on input use and production contributed to the gap in the returns to endowments effect.

Regression estimates from the selection equation when assessing gender patterns in labor allocation to avocado production and other activities, showed that increase in education had a positive effect on participation in avocado production, but a negative effect on wage employment for males. This finding complements earlier findings by Sikei et al., (2009) from Kakamega. We found that females participated and spent less time in avocado production and wage employment than their male counterparts when there were children under age five in the household. Assets and non- labor income were positively related to avocado production and non-farm self-employment, but negatively correlated with wage employment for males and females but at different intensities. Credit constraints lowered female time use in avocado production but did not seem to affect male time use. The results suggested that, demographic and socio-economic factors affected male and female labor behavior differently (Ilahi, 2001; Schindler, 2008).

Assessment of the role of avocado contract farming on gender labor allocation indicated that with the exception of marketing activities which had a negative but statistically insignificant coefficient for women, contract farming increased participation and time use of both men and women in avocado production. The positive relationship between female participation and time use in avocado harvesting which is traditionally considered a man's role suggests changing gender roles in avocado contract farming. Other factors such as age reduced female participation in various activities, but did not seem to affect male participation and time use. The number of children under five years also reduced female participation but increased male participation and time use in marketing. Education increased male participation in marketing but showed no statistical significance for females. Training in avocado agronomy and marketing increased male participation in the various activities, but was statistically insignificant for females in all activities. Credit constraints reduced participation and time use for both males and females in almost all tasks. Marital status, the number of *H*ass trees a household owned, the number of meetings a farmer attended in the last twelve months and voting in avocado group meetings were also significant predictors.

Turning to women empowerment and food security, we found a negative and significant relationship between household food insecurity and women's empowerment score after controlling for endogeneity and non-linearity of the empowerment variable. We also found that women were mostly disadvantaged in access to and decision making on credit, control over use of income and assets ownership domains. Women's empowerment in production decisions and the ownership of productive resources are channels through which women's empowerment influence food security. Other covariates such as education, plot size, adoption of soil conservation technology, fertile and deep soil depth were also significant in reducing food insecurity.

5.3 Conclusions

Several conclusions can be drawn from findings of this thesis. The study found that the number of *Hass* avocado trees owned is an important determinant of contract participation. *Hass* is the most preferred variety on the export market, but Kenyan production is dominated by local varieties which are less preferred. This finding suggests the need for farmers to plant more *Hass* variety to enhance participation in contract farming and in the export market.

We found household assets to play a significant role in contract participation and that contract farmers hired more labor for avocado production than non-contract farmers. With the growing national and global demand for avocados, the positive relationship between contract farming and hired labor signifies that avocado contract farming has the potential for rural job creation. Training in avocado agronomy and the provision of production and marketing information were also important predictors of contract farming. Enhancing avocado farmer's capabilities through training and extension services as well as disseminating production and marketing information not only improves contract participation but also the quality of production and the bargaining power of farmers in contract arrangements. It also helps them receive competitive prices for their output. The findings suggest that in general, training, marketing and production information are essential for contract participation.

The findings also indicated that the cost of transporting avocados to market and frequency of attending avocado group meetings were positively correlated with contract participation. Due to the bulky nature of avocados, transportation of the crop to the market poses a huge financial challenge to farmers. Thus contract farming serves as a relief in addressing this constraint since exporters in most cases pick up the crop at designated areas. The significant and positive relationship between frequency of group meeting attendance and contract farming showed that commitment to collective action has the potential of enabling farmers to participate in contract farming and the export market.

Evidence from gap analysis suggested that the major sources of gap in production outcomes were due to differences in endowments and returns to endowments. The number of *Hass* trees owned, hired labor, land size owned, training in avocado agronomy and practices and the provision of production and marketing information, age and education were prominent contributors to the gap. The significant effect of these variables in influencing both avocado contract farming and differentials in production outcomes shows that addressing both the resource and the returns to endowments gaps is important for improving avocado production, smallholder welfare and the sector as a whole. Land size mostly determines the number of avocado trees a farmer can plant. This means that with more land, farmers will have the opportunity to grow more *Hass* trees and enhance their chances of participating in contract farming.

Furthermore, results from gender labor allocation to production analysis, illustrated that increase in male education boosts incentives for participation in avocado production and reduces time use in wage employment. This means that with the modernization of agricultural value chains, education is an imperative asset in avocado contract farming. The presence of young children in the household had heterogeneous effects on gender and time use. Specifically, the presence of young children had a more disabling effect on female participation and time use in avocado production and wage employment than for males. Although young children are intrinsic part of family life, the disproportionate cost their presence have on female participation and time use underpins the need for public and family support arrangements to enhance female labor supply to avocado production and wage employment.

We also found that unlike for males, credit constraints served as a barrier to participation of females in avocado production. The implication of this finding is that liquidity constrained females may be excluded from the export market and from the benefits of a potential growth sector. The observed varying effects of exogenous factors on male and female participation and time use in avocado production and other economic activities showed that gender is an important factor in household labor allocation decisions. The study identified household assets endowment and non-labor income as important correlates facilitating avocado production and non-farm self-employment. Participating in these activities requires both material and financial resources. The significant relationship shows the complimentary role of assets and non-farm income in providing incentives and capacity for undertaking these activities.

The results further indicated that there is a gender gap in avocado marketing under contract farming. The limited participation of women in avocado marketing suggests that female avocado farmers are not well integrated in all aspects of avocado production. The study also found evidence of changing traditional gender roles, with women performing tasks like harvesting of avocados previously considered a man's job; thus suggesting the need for innovative strategies that could aid or address constraints in performance of different tasks. The study also showed that training in avocado agronomy and marketing enhanced the ability of male farmers in the performance of avocado production and marketing tasks. The insignificant effect of training in these activities for females is probably due to their exclusion since they do not own avocado trees. The importance of training in production and marketing activities suggests the need for females to be incorporated in such trainings even if they are not owners of the trees.

Lastly, women's empowerment in agriculture has the potential of improving household food security. However, the effect is underestimated in models that do not control for endogeneity of women's empowerment and overestimated for models that do not account for the non-linearity of the women's empowerment score. Furthermore, majority of rural women were disempowered in access to and decision making on credit, while women's asset ownership and decision making on production were important channels through which women's empowerment affect household food security. Education, land size, soil characteristics and management practices are also vital for food security.

The thesis contributes to literature in five ways. First we provide empirical literature from Kenya on: the drivers of avocado contract faming; sources of mean gap in quantities of avocadoes harvested and sold by contract and non-contract smallholders; and factors explaining those gaps. Second, we provide quantifiable evidence of gender patterns in labor allocation to avocado production, other crop farming, wage and non-farm self-employment using a two tier estimation procedure of participation and intensity of time use. We further assessed the role of gender in all avocado production activities. The analysis was done separately for males and females. Third we examined the effect of women's empowerment on aggregated food insecurity score and food insecurity prevalence using HFIAS measure of food insecurity. Fourth, we used the women's empowerment in agriculture score which captures the roles and extent of women's empowerment in agriculture to examine the relationship between women's empowerment and food security. Lastly, we used estimation techniques that controlled for potential endogeneity and non-linearity of the empowerment variable in the food security model and also used heteroscedasticity for identification and estimation of the endogenous women's empowerment regression model in the absence of available external instruments.

5.4 Policy implications

The findings from this thesis have several policy implications for improving smallholder avocado production and household food security. First, the number of *Hass* trees owned was a major determinant of contract farming. Kenya's competitiveness in the global avocado market is also dependent on the alignment of production to the increasing demand for *Hass* variety. Increasing the production of Hass presents a good opportunity not only for farmers but for their communities and the country as a whole. Thus the Murang'a County government should encourage farmers to take advantage of this growth opportunity to invest in Hass avocado farming. Extension officers can also trained farmers who have less preferred avocado variety trees to graft then into Hass.

The result showed that household assets played a significant role in the uptake of contract farming. It is therefore recommended that the government assists farmers with needed resources to diversify their agriculture portfolio and also engage in trade and other livelihood strategies that could strengthen their assets base.

Land is an important factor in both avocado production and food security; however, due to the inelasticity of land, there is a need for policy interventions that could improve land productivity. The potential areas of intervention could be sensitizing and training farmers to adopt modern farming technology such as improved seeds and fertilizers and also engaging in land management agronomy and sustainable agricultural intensification practices.

The demand for hired labor for contract farming is an indication that with the growing market demand for avocados, increase in contract farming is likely to create more jobs and thus reduce rural poverty. There is need for the County government to sensitize smallholders on the employment and welfare enhancing benefits of investing in avocado contract farming. The County government can initiate discussions with smallholders on strategies that could provide more employment opportunities. For instance, avocados that do not meet export requirement could be processed by smallholders into avocado oil which could be used locally or exported.

Improved communication flow helps in the production of healthier avocados, fetching better price for farmers and is an important determinant of contract participation as deduced from our result. The Ministry of Agriculture introduced the National Farmers Information Service (NAFIS) to provide farmers with market-based information through their mobile phones. We however recommend that extension officers be a part of that system to better explain those messages to illiterate farmers who may not be able to understand the information.

Avocado group membership serves as an important anchor and determinant of contract farming: Group membership provides more bargaining power for farmers in terms of negotiating contract terms and also gives confidence to farmers to participate in contract schemes. We thus recommend that both extension officers and local authorities should encourage and provide support to existing agricultural groups and encourage the formation of new groups in communities where there are none.

Farmer's knowledge in avocado agronomy was the main source of gap in production between contract and non-contract farmers. To close the gap, we recommend that government provides the necessary platform to train farmers in avocado agronomic practices like grafting, pruning, fertilizer application and harvesting.

Household composition, particularly the presence of young children limits women's participation and time use in avocado production and wage employment to improve their livelihoods. There is need for the state department of gender affairs to stimulate positive discussion around greater collaboration and equity in roles and responsibilities within the household. Such discussions may provide suggestions as to how women farmers can fully participate in these activities even when there are young children in the household to care for.

The limited participation of women farmers in avocado production due to credit constraints suggests the need for policies that encourage the growth of both informal and formal credit institutions in rural areas that target the agricultural sector. Collateral requirements and interest rates can also be negotiated to ensure flexibility for women to access credit. Moreover, the government women enterprise fund initiative can also be scaled up to target women farmers.

The changing gender role in avocado contract farming suggests the need for extension workers to work with women farmers in identifying their production constraints and possible strategies on way forward. Since both men and women are involved in avocado production and women are mostly excluded from training provided by exporters, we recommend that government and private sector partners work with exporters to implement avocado agronomic and GAP training so that women farmers will also benefit from those trainings. Incorporating women farmers in trainings would enhance their efficiency and the quality of fruits produce.

Women's empowerment in agriculture played an important role in reducing household food insecurity. Empowering to own and control productive resources and also participation in production decisions making were found as major channels through which empowerment reduced food insecurity. Women were however mostly disempowered in access to and decisions on credit. We thus recommend that government implements policy reforms and strategic interventions that would enhance women's asset ownership, credit access and empower women to make more production decisions and thus reduce food insecurity.

The close link between soil fertility, soil depth and food security suggests that policy interventions that improve soil characteristics also improve food security. We recommend that farmers invest in soil fertility by investing in fertilizers. Specifically, the use of organic fertilizer is highly encouraged as it reduces acidity and helps improve the structure of the soil. Additionally, extension officers can provide training to help farmers adopt soil conservation technics such as terracing, tree planting as well as mixed cropping to ensure sustainable agricultural intensification.

5.5 Areas for further research

While this study contributed to contract farming literature as a tool for improving smallholder welfare by pointing to drivers of smallholder avocado contract farming and factors that explain differentials in avocado production outcomes between contract and non-contract farmers, contract farming however differs by crop characteristics and contract type. Future studies could provide a broader picture of contract farming by investigating avocado contract farming and other crops produced based on the type of contract and its welfare effects. This could not be explored by this study due to data limitations.

Moreover, domestic activities such as fetching water, cooking, cleaning and other household chores could also affect household labor allocation patterns. This study mainly focused on gender patterns in labor allocation to avocado production under contract and non-contract scenarios as well as on other economic activities due to data limitations. Future studies should investigate how such activities affect male and female participation and time use in avocado production.

Although our study makes important contribution to the literature on women's empowerment and food security, the dynamic nature of food security requires the use of panel data to tease out the dynamic impacts associated with women's empowerment in agriculture and food security. The cross sectional nature of our data could not support such analysis. Furthermore, this dataset only focused on a few regions in Kenya. There is need for further research using nationally representative panel data to fully understand the relationship between women's empowerment and food security.

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APPENDIX 1

SMALLHOLDER AVOCADO CONTRACT FARMING IN KENYA: DETERMINANTS AND DIFFERENTIALS IN PRODUCTION OUTCOMES

a. Derivation of Contract Participation Model

Following Singh et al. (1986), we formulate the farm household utility maximization problem subject to income and resource constraint.

$$U = u(C^m, C^a, l, Z^h) \tag{A1.1}$$

Where U is the utility, C^m, C^a, l_i and Z^h are market purchased goods, farm produced goods, leisure and household characteristics. The household maximizes utility subject to time constraint T allocated between contract farming $L_{fc}(\tau)$, off-farm work L_{off} and leisure l (A1.2) technology constraint equation (A1.3) and income constraint equation (A1.4)

$$T = L_{fc}(\tau) + L_{Off} + l \tag{A1.2}$$

The household faces a production function q that is concave and twice differentiable consisting of vector of inputs (X) that is condition on contract participation (τ), farm labor dedicated to contract farming, contract participation and production technology characteristics (E)

$$q = q(X(\tau), L_{fc}(\tau), \tau, E) \qquad \tau \geq 0 \tag{A1.3}$$

The basic agriculture household model (AHM) assumes perfect market. However, with the pervasive market failure experienced by smallholders, we relax the assumption of perfect market and incorporate transaction costs that are due to differences in buying and selling commodities and also for acquiring information for production and marketing; as well as returns to hired labor and own labor sales. Transaction cost is incorporated into the budget constraint model through shadow prices.

$$p^s C + (t^c + p^m - p^s)C^m = p^s q - wX(\tau) + w^n L_{off} - (t^q - p^m + p^s)q^m + Y \tag{A1.4}$$

Where p^s and p^m are endogenous shadow prices and market prices respectively, $C = C^m + C^a$ represents total consumption, t^c and t^q denote transaction in purchase and sales of commodities respectively, $q = q^a + q^m$ denotes total crops produced for consumption and marketing, w and w^n are price of inputs and off-farm wage earned and Y denote other transfers received by households. We substitute equation (A1.3) into equation (A1.4) to get net income constraint (Huffman 1991).

$$p^s C + (\mathrm{t}^c + p^m - p^s)\mathrm{C}^m = p^s\{\mathrm{q}(\mathrm{X}(\tau), \mathrm{L}_{fc}(\tau), \tau, \mathrm{E})\} - wX(\tau) + \mathrm{w}^n L_{off} - (t^q - p^m + p^s)$$

$$\{\mathrm{q}^m(\mathrm{X}(\tau), \mathrm{L}_{fc}(\tau), \tau, \mathrm{E})\} + Y \qquad \text{(A1.5)}$$

We then form the Lagrangian function which incorporates the objective function and budget constraint equations. Optimality conditions are obtained by maximizing the Lagrangian expression L over a set of choice variables

$$L = u(\mathrm{C}^m, C^a, \mathrm{l}, Z^h) + \lambda\{p^s\{\mathrm{q}(\mathrm{X}(\tau), \mathrm{L}_{fc}(\tau), \tau, \mathrm{E})\} - wX(\tau) + \mathrm{w}^n L_{off} - (t^q - p^m$$

$$+\mathrm{p}^s)\{\mathrm{q}^m(\mathrm{X}(\tau), \mathrm{L}_{fc}(\tau), \tau, \mathrm{E})\} + Y - \{p^s C + (\mathrm{t}^c + p^m - p^s)\mathrm{C}^m\}$$

$$+\mu\{L_{fc}(\tau) + L_{off} - T\} \qquad \text{(A1.6)}$$

Where λ and μ are lagrange multipliers. The optimal condition for contract participation decision can be obtained from the following Kuhn-Tucker conditions

Optimal allocation of purchased goods

$$\frac{\partial L}{\partial C^m} = \frac{\partial U}{\partial C^m} - \lambda(\mathrm{t}^c + p^m - p^s) = 0 \qquad \text{(A1.7a)}$$

Optimal allocation of inputs

$$\frac{\partial L}{\partial X} = \lambda\left\{p^s \frac{\partial q}{\partial X} - w - (t^q - p^m - p\right\}\frac{\partial q^m}{\partial X} = 0 \qquad \text{(A1.7b)}$$

Optimal condition for contract participation

$$\frac{\partial L}{\partial \tau} = \lambda\left[p^s\left\{\left(\frac{\partial q}{\partial X}\right)\left(\frac{\partial X}{\partial \tau}\right) + \left(\frac{\partial q}{\partial L_{fc}}\right)\left(\frac{\partial L_{fc}}{\partial \tau}\right) + \frac{\partial q}{\partial \tau}\right\} - w\left(\frac{\partial X}{\partial \tau}\right) - (t^q - p^m\right.$$

$$\left.+p^s)\left\{\left(\frac{\partial q^m}{\partial X}\right)\left(\frac{\partial X}{\partial \tau}\right) + \left(\frac{\partial q^m}{\partial L_{fc}}\right)\left(\frac{\partial L_{fc}}{\partial \tau}\right) + \frac{\partial q^m}{\partial \tau}\right\}\right] + \mu\left[\left(\frac{\partial L_{fc}}{\partial \tau}\right)\right] \leq 0 \qquad \text{(A1.7c)}$$

Optimal allocation of farm labor to contract farming defined as:

$$\frac{\partial L}{\partial L_{fc}} = \lambda\left[p^s\left(\frac{\partial q}{\partial L_{fc}}\right) - (t^q - p^m + p^s)\left(\frac{\partial q^m}{\partial L_{fc}}\right) + \mu\right] = 0 \qquad \text{(A1.7d)}$$

Following (Huffman 1991), the optimal condition for contract participation can be estimated as a reduced form equation which can be solved by substituting equation (A1.b) and (A1.7d) into (A1.7c)

$$\frac{\partial L}{\partial \tau} = \lambda\left[p^s \left\{ \left(\frac{\kappa}{p^s} \right) - \alpha \left(\frac{\partial q^m}{\partial X} \right) \left(\frac{\partial X}{\partial \tau} \right) + \left(\alpha \frac{\partial q^m}{\partial L_{fc}} - \frac{\mu}{\lambda} \right) \left(\frac{\partial L_{fc}}{\partial \tau} \right) + \frac{\partial q}{\partial \tau} \right\} - w \left(\frac{\partial X}{\partial \tau} \right) - (t^q - p^m \right.$$

$$\left. + p^s) \left\{ \left(\frac{\partial q^m}{\partial X} \right) \left(\frac{\partial X}{\partial \tau} \right) + \left(\frac{\partial q^m}{\partial L_{fc}} \right) \left(\frac{\partial L_{fc}}{\partial \tau} \right) + \frac{\partial q^m}{\partial \tau} \right\} \right] + \left[\left(\frac{\partial L_{fc}}{\partial \tau} \right) \right] \leq 0 \qquad \text{(A1.7e)}$$

Where $\alpha = (t^q - p^m - p^s)$

Table A1: OLS Estimates of Avocado Quality, Quantities Harvested and Sold Accounting for Selection bias

	Quantities Harvested		Quantities Sold		Quality Sold	
Variable	Non-contract	Contract	Non-contract	Contract	Non-contract	Contract
Age of household head	-0.027***	-0.001	-0.028*	-0.004	-0.003	-0.009***
(years)	(0.010)	(0.005)	(0.016)	(0.007)	(0.005)	(0.003)
Gender dummy (Male=1)	0.311**	0.107	0.349	0.134	0.062	0.133*
	(0.154)	(0.143)	(0.240)	(0.193)	(0.083)	(0.083)
Household size (no. of	-0.104**	-0.002	-0.114	-0.034	-0.005	0.000
Persons)	(0.046)	(0.034)	(0.072)	(0.046)	(0.025)	(0.020)
Education of household head (years)	0.024*	0.040***	0.004	0.060***	0.012*	-0.019**
	(0.013)	(0.017)	(0.020)	(0.023)	(0.007)	(0.010)
Main occupation of household (farming=1)	0.256	-0.036	0.191	0.030	0.152	-0.099
	(0.194)	(0.173)	(0.303)	(0.233)	(0.103)	(0.100)
No of productive *Hass* trees	-0.024	0.018***	-0.027***	0.020***	-0.004	0.001**
	(0.017)	(0.003)	(0.027)	(0.004)	(0.010)	(0.002)
No of productive *Fuerte* trees	0.035***	0.049***	0.040***	0.058***	0.000	0.002
	(0.005)	(0.006)	(0.008)	(0.009)	(0.003)	(0.004)
Land owned (acre)	0.052*	-0.023	0.025	-0.025	0.022*	0.037
	(0.029)	(0.029)	(0.046)	(0.039)	(0.015)	(0.017)
ln total assets (Ksh)	-0.081*	0.038	-0.065	0.019	-0.002	0.003
	(0.047)	(0.037)	(0.073)	(0.050)	(0.025)	(0.022)
Non-farm income (Ksh)	0.014	-0.031*	0.015	-0.033	-0.005	-0.006
	(0.016)	(0.018)	(0.025)	(0.025)	(0.008)	(0.011)
Credit constrained (yes=1)	-0.067	-0.059	-0.149	0.010	0.054	0.037
	(0.117)	(0.150)	(0.183)	(0.205)	(0.060)	(0.089)
Hired labor (yes=1)	-0.006***	0.000*	-0.007*	0.001*	-0.001	0.000*
	(0.002)	(0.000)	(0.004)	(0.000)	(0.001)	(0.000)
Cost of transporting avocado to market (Ksh)	-6.671***	-0.057	--7.656***	-0.101	-0.389	0.024
	(1.761)	(0.067)	(2.746)	(0.091)	(0.976)	(0.039)
Group meeting attendance (no. in a year)	-0.081***	0.006**	-0.058*	0.007	-0.013	0.001
	0.016)	(0.005)	(0.025)	(0.006)	(0.009)	(0.003)
Trusting people (index)	-0.128	0.429	-0.680	0.417	-0.299	-0.231
	(0.002)	(0.399)	(0.564)	(0.538)	(0.187)	(0.232)
Received information on avocado production and marketing (yes=1)	-0.019	0.697***	0.209	1.207***	-0.002	0.180
	(0.110)	(0.209)	(0.172)	(0.281)	(0.058)	(0.124)
House member received	-2.932***	0.044	-3.069**	-0.097	-0.153	-0.089***

training in avocado prod year (yes=1)						
	(0.978)	(0.217)	(1.526)	(0.292)	(0.547)	(0.126)
Pruning at least once a year (yes=1)	0.054	0.056	0.282*	0.031**	0.040	0.073
	(0.092)	(0.108)	(0.144)	(0.145)	(0.047)	(0.063)
Grafted avocado tree (yes=1)	0.369***	0.125***	0.551***	-0.069***	-0.046	0.103
	(0.104)	(0.166)	(0.161)	(0.224)	(0.053)	(0.097)
Fertilizer & pesticide Application rate (kg/tree)	0.001**	0.023***	0.005*	0.003**	0.011*	0.032***
	(0.002)	(0.101)	(0.002)	(0.001)	(0.003)	(0.122)
Keeping records of input use & Prod (yes=1)	0.080	-0.053	0.220	-0.112	-0.176*	0.088
	(0.178)	(0.143)	(0.277)	(0.192)	(0.091)	(0.083)
IMR	-0.504	0.093	-1.040*	-0.032	-0.371	-0.006
	(0.688)	(0.198)	(0.524)	(0.267)	(0.655)	(0.115)
Constant	16.952***	6.690***	16.741***	6.543***	0.132***	1.055***
	(3.134)	(0.562)	(4.886)	(1.025)	(0.260)	(0.442)
N	523	263	523	263	523	263
R-squared	0.323	0.415	0.202	0.375	0.083	0.118

Robust standard error in parenthesis *, **, *** Significant at 10%, 5% and 1%

Table A2: OLS Oaxaca-Blinder Aggregate Decomposition of Total Harvest, Sales and Quality

	Quantity harvested	Quantity sold	High quality grade
	Coef.	Coef.	Coef.
Mean prediction Contract farmer	8.745***	8.535***	0.627***
	(0.065)	(0.084)	(0.031)
Mean prediction Non-contract farmer	8.248***	7.957***	0.426***
	(0.052)	(0.074)	(0.023)
Difference	0.497***	0.578***	0.202***
	(0.083)	(0.112)	(0.038)
Endowment effects	-0.442**	-0.592**	-0.007
	(0.093)	(0.124)	(0.048)
Coefficient effects	-1.091*	-1.205*	-0.231*
	(0.454)	(0.602)	(0.169)
Interaction effects	1.036*	1.219*	0.037
	(0.456)	(0.605)	(0.172)

Robust standard error in parenthesis *, **, *** Significant at 10%, 5% and 1%

Table A3: Variables Contributing to Net Gap in Avocado Quality, Harvested and Sold Quantities

	Endowment Effect	Coefficient Effect	Interaction Effect
Variables	Coef.	Coef.	Coef.
Quantities harvested			
Age of household head (years)	0.003	-1.610**	0.051
	(0.010)	(0.697)	(0,034)
Household size (no. of persons)	0.002	-0.370*	0.009
	(0.003)	(0.210)	(0.015)
No of productive *Hass* trees	-0.164***	0.610**	0.368**
	(0.034)	(0.262)	(0.172)
No of productive *Fuerte trees*	-0.054	-0.083*	0.022
	(0.033)	(0.049)	(0.016)
Land owned (acre)	0.010	0.179*	-0.053
	(0.013)	(0.010)	(0.025)
ln total assets (Ksh)	-0.012	-1.168**	0.038
	(0.123)	(0.586)	(0.223)
Non-farm income (Ksh)	-0.002	0.454*	0.002
	(0.013)	(0.244)	(0.010)
Hired labor (yes=1)	-0.043*	-0.845***	-0.644*
	(0.025)	(0.316)	(0.251)
Cost of transporting avocado to market (Ksh)	0.011	-1.090**	0.992**
	(0.010)	(0.119)	(0.436)
Rec. information on avocado production and marketing (yes=1)	-0.177***	-0.640***	0.182**
	(0.057)	(0.212)	(0.063)
Group meeting attendance (no. in a year)	-0.016	-0.945*	0.243***
	(0.013)	(0.195)	(0.082)
House member rec. training in avocado prod year (yes=1)	-0.223	-2.212***	1.532***
	(0.112)	(0.749)	(0.525)
IMR	0.075	0.943*	-0.008
	(0.159)	(1.952)	(0.027)
Quantities Sold			
Education of household head (years)	-0.023	-0.465*	0.021
	(0.019)	(0.249)	(0.019)
No of productive *Hass* trees	-0.180***	-0.675*	0.427
	(0.046)	(0.403)	(0.260)
Hired labor (yes=1)	-0.056*	0.900*	-0.686*

	(0.033)	(0.478)	(0.372)
Cost of transporting avocados to market (Ksh)	0.015	-1.246**	1.134**
	(0.015)	(0.601)	(0.181)
Rec. information on avocado production & marketing (yes=1)	-0.306***	-0.892***	0.253**
	(0.079)	(0.295)	(0.089)
House member rec. training In avocado prod year (yes=1)	0.050	-2.209*	1.530*
	(0.178)	(1.157)	(0.805)
Group meeting attendance (no.in a year)	-0.019	-0.701**	0.180**
	(0.018)	(0.288)	(0.088)
Grafted avocado trees (yes=1)	0.006	0.548**	-0.861**
	(0.030)	(0.244)	(0.042)
IMR	1.309*	0.837	-0.540
	(0.662)	(1.723)	(1.111)
Quality sold			
Land owned (acre)	-0.016*	-0.034	0.006
	(0.009)	(0.055)	(0.010)
Education of household head (years)	0.009	0.257***	-0.014
	(0.007)	(0.098)	(0.010)
Main occupation of household head (farming=1)	0.001	0.221*	-0.003
	(0.003)	(0.127)	(0.005)
Keeping records of input & production (yes=1)	-0.009	-0.043**	-0.026*
	(0.008)	(0.021)	(0.014)
IMR	-0.005	-0.255	-0.297
	(0.093)	(0.464)	(0.539)

Robust standard error in parenthesis *, **, *** Significant at 10%, 5% and 1%

APPENDIX 2: QUANTIFYING GENDER PATTERNS IN LABOR ALLOCATION TO AVOCADO PRODUCTION IN KENYA

Table A4: Test against Tobit specification (Ho: Tobit specification is appropriate)

	Adult Females			Adult Males		
	LR Chi2(13)	Prob >chi2	Conclusion	LR Chi2(13)	Prob >chi2	Conclusion
Avocado labor time	47.18	0.0001	Ho rejected	46.09	0.0001	Ho rejected
Other farming activities	50.47	0.0000	Ho rejected	84.65	0.0000	Ho rejected
wage labor time	318.8	0.0000	Ho rejected	290.32	0.0000	Ho rejected
Non-farm self-employment	296.9	0.0000	Ho rejected	265.01	0.0000	Ho rejected

Table A5: Test against Tobit specification (Ho: Tobit specification is appropriate)

Test against Tobit specification	Female			Male		
	LR Chi2(13)	Prob >chi2	Conclusion	LR Chi2(13)	Prob >chi2	Conclusion
Land preparation	-88.7	1.0000	Fail to reject Ho	-61.4	1.0000	Fail to reject Ho
Weeding	-102.63	1.0000	Fail to reject Ho	-116.09	1.0000	Fail to reject Ho
Harvesting	-84.71	1.0000	Fail to reject Ho	-43.59	1.0000	Fail to reject Ho
Marketing	-402.93	1.0000	Fail to reject Ho	-356.05	1.0000	Fail to reject Ho

Table A6: Maximum Likelihood estimates of DHM for Female and Male Labor Time Allocation Decision

	Participation Decision							
Variable	Avocado Production		Other Farming Activities		Wage Employment		Non-Farm Self-Employment	
Household characteristics	Female	Male	Female	Male	Female	Male	Female	Male
Age of male/female (years)	0.0194*	0.0092	0.0191	-0.0128	-0.0275**	-0.0474***	-0.0433***	-0.0215
	(0.0104)	(0.0111)	(0.0139)	(0.0148)	(0.0124)	(0.0125)	(0.0122)	(0.0117)
Age squared	-0.3283	-0.1461	-0.2754	0.2865	0.3170	0.7869***	0.7202***	0.3813
	(0.1999)	(0.2208)	(0.2702)	(0.2923)	(0.2291)	(0.2434)	(0.2298)	(0.2338)
Education of adult male/female (years)	0.0098	0.0335**	-0.0076	0.0248	-0.0181	-0.0384**	-0.0024	-0.0209
	(0.0149)	(0.0167)	(0.0201)	(0.0222)	(0.0169)	(0.0172)	(0.0164)	(0.0186)
Gender of head dummy (male=1)	-0.0782	-0.0894	-0.3861***	-0.3139	0.3001***	0.3364**	0.0689	-0.2941
	(0.1070)	(0.1438)	(0.1532)	(0.2144)	(0.1161)	(0.1493)	(0.1173)	(0.1429)
Age of household head (years)	-0.0092**	-0.0117***	-0.0083	-0.0089	-0.0121***	-0.0023	0.0101**	-0.0011
	(0.0040)	(0.0046)	(0.0051)	(0.0064)	(0.0045)	(0.0045)	(0.0042)	(0.0045)
Education of household head (years)	0.0150	-0.0200	0.0509***	-0.0033	-0.0409***	-0.0161	-0.0244*	0.0248
	(0.0130)	(0.0157)	(0.0164)	(0.0199)	(0.0144)	(0.0162)	(0.0143)	(0.0174)
Occupation of Household head (Farming=1; 0 otherwise)	0.5159***	0.5583***	0.5991***	0.6238***	-0.2409**	-0.3499***	-0.7925***	-0.6736
	(0.1114)	(0.1085)	(0.1413)	(0.1359)	(0.1138)	(0.1107)	(0.1156)	(0.1133)
Number of children (0-5) years	-0.0689	-0.1774*	0.1515	0.0147	-0.2163**	-0.0825	0.3285***	0.4485
	(0.0997)	(0.1054)	(0.1404)	(0.1409)	(0.1072)	(0.1117)	(0.0995)	(0.1116)
Number of children (6-14) years	-0.0158	-0.0368	-0.0588	-0.0453	0.0328	-0.0223	0.0462	0.0144
	(0.0434)	(0.0439)	(0.0573)	(0.0625)	(0.0464)	(0.0468)	(0.0456)	(0.0475)
Physical and financial assets								
Ln total assets (Ksh)	0.1327***	0.1671***	-0.0795	-0.0193	-0.0571	-0.0447	0.1351***	0.0820
	(0.0414)	(0.0405)	(0.0514)	(0.0490)	(0.0431)	(0.0404)	(0.0427)	(0.0403)
Non-labor income (yes=1)	0.2671***	0.2609***	0.1154	0.0579	-0.6830***	-0.6111	-0.3790***	-0.6055
	(0.0935)	(0.0990)	(0.1221)	(0.1290)	(0.1115)	(0.1118)	(0.1053)	(0.1192)
Total land owned (acre)	-0.0180	0.0045	-0.0326	0.0047	-0.0523	-0.0132	0.0267	0.0158

	(0.0224)	(0.0270)	(0.0248)	(0.0359)	(0.0322)	(0.0259)	(0.0206)	(0.0229)
Owned livestock size	0.0676	-0.0261	0.1611	0.2963	-0.1332	-0.1804	-0.0287	-0.0146
	(0.1162)	(0.1141)	(0.1314)	(0.1453)	(0.1413)	(0.1449)	(0.1302)	(0.1292)
Social Capital								
Group membership (yes=1)	0.1386	0.1888*	0.2176*	0.2679**	0.2447**	0.1994*	0.0998	-0.0286
	(0.0982)	(0.0998)	(0.1262)	(0.1250)	(0.1142)	(0.1122)	(0.1162)	(0.1156)
Distance to market (km)	0.0144***	0.0116***	0.0204***	0.0176***	-0.0161**	-0.0048	0.0017	-0.0004
	(0.0048)	(0.0047)	(0.0066)	(0.0063)	(0.0066)	(0.0050)	(0.0048)	(0.0049)
Credit constrained (yes=1)	-0.1022	-0.1217	0.5643***	0.9147***	0.0961	0.1140	0.2286**	0.0413
	(0.0994)	(0.1036)	(0.1678)	(0.2154)	(0.1043)	(0.1073)	(0.1080)	(0.1174)
Constant	0.5516	-0.4797	2.9072*	-0.3891	0.1892	-3.0870**	-5.4384***	-2.4991
	(1.1582)	(1.3450)	(1.5597)	(1.8190)	(1.2923)	(1.4439)	(1.3119)	(1.4039)
Wald chic2(16)	71.02	53.41	140.3	147.39	68.91	83.84	46.71	49.15
Prob>chi2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
Log pseudolikelihood	-158.948	-140.654	-161.147	-157.665	-449.893	-482.742	-439.248	-442.837
Observations	1,109	1,086	1,109	1,086	1,086	1,109	1,109	1,086

Robust standard errors in parenthesis, *, **, *** Significant at 10%, 5% and 1%

Table A7: Maximum Likelihood estimates of DHM for Female and Male Intensity of Labor Time Allocation

Variable	Intensity of Participation: Avocado Production		Other Farming Activities		Wage Employment		Non-Farm Self-Employment	
Household characteristics	Female	Male	Female	Male	Female	Male	Female	Male
Age of male/female (years)	-0.0002	0.0035	0.0043*	0.0117***	0.0051**	-0.0010	0.0038	0.0017*
	(0.0028)	(0.0031)	(0.0023)	(0.0028)	(0.0025)	(0.0031)	(0.0027)	(0.0035)
Age squared	-0.0244	-0.0654	-0.0571	-0.2238***	-0.0841*	0.0289	-0.0385	-0.0125
	(0.0534)	(0.0602)	(0.0450)	(0.0573)	(0.0476)	(0.0628)	(0.0523)	(0.0675)
Education of adult male/female (years)	-0.0052	-0.0038	0.0009	0.0092**	0.0012	-0.0040	0.0052	0.0006
	(0.0040)	(0.0048)	(0.0035)	(0.0044)	(0.0036)	(0.0041)	(0.0039)	(0.0045)
Gender of head dummy (male=1)	-0.0636***	0.0162	-0.0167	0.0317	-0.0310	-0.0160	-0.0338	-0.0814**
	(0.0277)	(0.0373)	(0.0242)	(0.0381)	(0.0263)	(0.0353)	(0.0280)	(0.0350)
Age of household head (years)	0.0017	-0.0003	0.0001	-0.0002	0.0006	0.0026*	0.0010	0.0002
	(0.0012)	(0.0013)	(0.0010)	(0.0012)	(0.0009)	(0.0014)	(0.0011)	(0.0013)
Education of household head (years)	0.0062	0.0050	0.0089***	-0.0018	-0.0047	-0.0015	-0.0012	0.0029
	(0.0038)	(0.0041)	(0.0032)	(0.0041)	(0.0030)	(0.0049)	(0.0033)	(0.0040)
Occupation of Household head (Farming=1; 0 otherwise)	0.0978***	0.1270***	0.1858***	0.1663***	-0.0190	-0.0075	-0.0530**	-0.0399
	(0.0394)	(0.0368)	(0.0382)	(0.0388)	(0.0301)	(0.0270)	(0.0249)	(0.0259)
Number of children (0-5) years	-0.1088***	-0.0746**	-0.0266	-0.0699**	0.0012	-0.0211	0.0154	0.0124
	(0.0360)	(0.0351)	(0.0270)	(0.0354)	(0.0291)	(0.0357)	(0.0188)	(0.0193)
Number of children (6-14) years	-0.0234*	-0.0247*	-0.0173	-0.0046	0.0286***	0.0416***	0.0042	0.0051
	(0.0130)	(0.0142)	(0.0117)	(0.0121)	(0.0086)	(0.0094)	(0.0136)	(0.0149)
Physical and financial assets								
ln total assets (Ksh)	0.0193*	0.0094	-0.0074	-0.0037	-0.0347***	-0.0199**	0.0004	-0.0094
	(0.0110)	(0.0108)	(0.0094)	(0.0098)	(0.0105)	(0.0097)	(0.0107)	(0.0118)
Non labor income (yes=1)	0.0047	-0.0143	0.1304***	0.1483***	0.0507*	0.1024***	0.0273	0.0078
	(0.0244)	(0.0251)	(0.0194)	(0.0210)	(0.0271)	(0.0301)	(0.0262)	(0.0338)

Total land owned (acre)	0.0125**	0.0166***	0.0026	-0.0048	0.0041	-0.0077	-0.0057	-0.0055
	(0.0058)	(0.0060)	(0.0055)	(0.0058)	(0.0054)	(0.0114)	(0.0050)	(0.0067)
Owned livestock size	-0.1160***	-0.1263***	-0.0096	0.0108	0.0407	0.0417	0.0646*	0.0532
	(0.0431)	(0.0433)	(0.0294)	(0.0297)	(0.0380)	(0.0331)	(0.0339)	(0.0366)
Social Capital								
Group membership (yes=1)	-0.0041	-0.0162	-0.0298	-0.0022	-0.0641**	-0.0998***	-0.1151***	-0.1316
	(0.0254)	(0.0262)	(0.0228)	(0.0254)	(0.0280)	(0.0260)	(0.0241)	(0.0237)
Distance to market (km)	0.0005	-0.0009	0.0003	-0.0013	0.0024*	0.0038***	-0.0022	0.0001
	(0.0011)	(0.0010)	(0.0009)	(0.0010)	(0.0013)	(0.0008)	(0.0021)	(0.0018)
Credit constrained (yes=1)	-0.0970***	-0.0355	-0.0251	-0.0263	-0.0333	-0.0006	-0.0027	-0.0261
	(0.0307)	(0.0291)	(0.0249)	(0.0277)	(0.0271)	(0.0277)	(0.0257)	(0.0316)
Constant	0.0091	0.2727	0.4121	1.2466***	1.2554***	0.4421	0.6815**	0.7714**
	(0.3141)	(0.3561)	(0.2659)	(0.3473)	(0.2598)	(0.3739)	(0.3056)	(0.3915)
Wald chic2(16)	71.02	53.41	140.30	147.39	68.91	83.84	46.71	49.15
Prob>chi2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
Log pseudolikelihood	-158.948	-140.654	-161.147	-157.665	-449.893	-482.742	-439.248	-442.837
lnsigma	-1.5779***	-1.5931***	-1.3747***	-1.3367***	-1.7653***	-1.7165***	-1.7669***	-1.7169***
	(0.0520)	(0.0524)	(0.0287)	(0.0298)	(0.0421)	(0.0453)	(0.0453)	(0.0431)
Sigma	0.2064	0.2033	0.2529	0.2627	0.1711	0.1797	0.1709	0.1796
	(0.0107)	(0.0107)	(0.0073)	(0.0078)	(0.0072)	(0.0081)	(0.0077)	(0.0077)
Observations	1,109	1,086	1,109	1,086	1,086	1,109	1,109	1,086

Robust standard errors in parenthesis, *, **, *** Significant at 10%, 5% and 1%

Table A8: Estimates of Female and Male Avocado Participation and Intensity of Labor Allocation

	Land Preparation		Weeding		Harvesting		Marketing	
Variable	Female	Male	Female	Male	Female	Male	Female	Male
Age of adults (years)	-0.135***	0.020	-0.115**	0.039	-0.143***	-0.001	0.045	-0.032
	(0.049)	(0.075)	(0.049)	(0.066)	(0.051)	(0.056)	(0.029)	(0.035)
Education (years)	-0.082	0.002**	-0.008	0.005**	0.105	0.355	0.179	-0.011
	(0.249)	(0.260)	(0.237)	(0.289)	(0.241)	(0.238)	(0.131)	(0.143)
Main occupation	3.828***	8.823***	7.188***	3.576*	6.287***	12.819***	0.275	6.377***
(Farming=1; 0 otherwise)	(1.912)	(2.003)	(1.810)	(2.149)	(1.696)	(1.991)	(1.005)	(1.210)
Marital status (Married=1)	2.736*	-3.026	-1.977	-1.740	-0.361	4.552**	-0.708	-1.854
	(1.530)	(3.337)	(1.345)	(2.716)	(1.332)	(2.172)	(0.734)	(1.362)
Household size (no. of persons)	1.115***	1.637***	1.041**	1.163**	-0.383**	0.848**	-0.095	0.236
	(0.407)	(0.460)	(0.422)	(0.515)	(0.321)	(0.446)	(0.198)	(0.248)
Number of children (0-5) years	-0.450	-0.082	-0.452**	-0.078	-0.154	1.400**	-0.670**	0.966**
	(0.455)	(0.559)	(0.422)	(0.266)	(0.373)	(0.483)	(0.245)	(0.325)
Number of mature *Hass* trees	0.067*	0.111**	0.104**	-0.078	0.100**	0.339**	0.055**	0.084***
	(0.050)	(0.053)	(0.043)	(0.077)	(0.035)	(2.039)	(0.026)	(0.022)
Number. of mature *Fuerte* trees	0.198	0.085	0.101	0.130	-0.156	0.004	0.147	0.087
	(0.219)	(0.165)	(0.183)	(0.272)	(0.146)	(0.134)	(0.127)	(0.104)
Non-labor income (Ksh)	0.181	0.842***	0.275	-1.514**	-0.086	0.213	0.305***	0.415***
	(0.298)	(0.229)	(0.227)	(0.238)	(0.191)	(0.203)	(0.115)	(0.138)
credit constraint (yes=1)	-3.955***	-3.544**	-1.119	-9.572**	-0.466	-2.620	-0.836	-2.553**
	(1.247)	(1.636)	(1.286)	(2.378)	(1.250)	(1.587)	(0.870)	(1.062)
Meeting attendance	0.214**	0.119***	0.287**	0.077	0.147**	0.213***	0.024	0.099**
	(0.058)	(0.066)	(0.068)	(0.091)	(0.067)	(0.060)	(0.030)	(0.043)
Voted in elections	5.385***	2.675	2.617**	5.505	2.073**	1.920	2.062***	0.710
	(1.337)	(1.633)	(1.346)	(1.953)	(1.422)	(1.421)	(0.698)	(0.810)
Attended training	0.793	0.273**	1.292	0.876	1.240	1.212**	0.546	2.808***
	(1.953)	(2.172)	(1.986)	(2.036)	(1.364)	(1.497)	(0.760)	(0.994)
Contract farmer (yes=1)	0.021*	2.862**	0.634**	-0.302	0.205**	1.339**	0.320	2.210***

	(2.175)	(2.326)	(1.861)	(2.201)	(1.468)	(1.720)	(0.812)	(1.093)
Constant	10.374**	-7.998*	9.839**	-8.579**	18.313**	-4.281***	-5.745**	-7.324***
	(4.332)	(4.664)	(4.383)	(5.840)	(5.118)	(4.407)	(2.624)	(2.769)
Var(e)	473.944	640.439	475.771	593.046	456.385	504.926	101.940	158.574
	(63.094)	(98.678)	(78.503)	(100.235)	(79.537)	(80.702)	(12.517)	(20.274)
[Female F(14, 1088)] [Male F(14, 1094)]	5.51	5.02	5.05	5.14	3.74	4.85	2.92	4.32
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Log pseudolikelihood	-4489.42	-4532.202	-4538.99	-2454.37	-4509.665	-4004.434	-2759.346	-2686.31
Observations	1,078	1,084	1,078	1,084	1,078	1,084	1,078	1,084

Robust standard errors in parenthesis, *, **, *** Significant at 10%, 5% and 1%

APPENDIX 3: THE EFFECT OF WOMEN'S EMPOWERMENT IN AGRICULTURE ON FOOD SECURITY IN KENYA

b. Derivation of the model for intra-household decision making

The essay adopts the static Nash bargaining framework for household labor allocation to farm and off-farm activity. Following Mendoza and Berlage (2002), the utility maximization of the gain from cooperation of two individuals $i \in \{m, f\}$ over a vector of consumption goods, including a shared public good C, and leisure L^i, a vector of household characteristics ϖ, V^i represents the threat point or indirect utility enjoyed by the individual outside the household. Z Represents non-labor income (I^i), prices of composite good (p_c), price of farm input (p_x), and market wage (W^i) given by (I^i, P_c, P_q, p_x, W^i) is specified as:

$$Max[\mathrm{U}^m(\mathrm{C}^m, \mathrm{L}^m : \varpi) - V^m(\mathrm{Z})][\mathrm{U}^f(\mathrm{C}^f, \mathrm{L}^f : \varpi) - V^f(\mathrm{Z})] \quad \text{(A3.1)}$$

Subject to:

$$Q = q(F^m, F^f, X; \xi) \quad \text{(A3.2)}$$

$$\mathrm{P}_q Q - P_x X + W(\mathrm{M}^m + M^f) + I^m + I^f = P_c C \quad \text{(A3.3)}$$

$$T = L^i + F^i + M^i \quad \text{(A3.4)}$$

$$F^i \geq 0, \; M^i \geq 0 \quad \text{(A3.5)}$$

Where equation (A3.2) is the production technology constraint Q which is the function of male and female farm labor F^m, F^f, inputs used in production of farm commodities X and a vector of production technology characteristic ξ assumed to be concave and twice differentiable , equation (A3.3) denotes the income or budget constraint with farm profits $\mathrm{P}_q Q - P_x X$, market wage receive from allocation of labor to off-farm activity by male and female household members W and non-labor income I^i. Equation (A3.4) represents total household time endowment T allocated to leisure L^i, farm production F^i and market or off-farm activities M^i by the household. A non-negativity constraint is imposed for farm and off-farm activity $F^i \geq 0,\; M^i \geq 0, \forall i \in \{m, f\}$.

The household then chooses the level of C, L^i, F^i and M^i to maximize utility (A3.1) subject to constraints (A3.2) - (A3.4). The Lagrangean for the constrained optimization problem is specified as:

$$L = [U^m(C, L^m) - V^m][U^f(C, L^f) - V^f]$$

$$+\lambda\{[P_q Q(F^m, F^f, X; \xi) - P_x X] + W^i(M^m + M^f) + I^m + I^f - P_c C\}$$

$$+\gamma^i(T^i - L^i - F^i - M^i)$$

$$+\sigma^i F^i + \varphi^i M^i \qquad \text{(A3.5)}$$

Where λ, γ^i, σ^i, φ^i are Langrange multipliers for the marginal value of income, household time farm and off-farm activity. Assuming an interior solution, the first order Kuhn Tucker conditions are derived.

$$\frac{\partial L}{\partial C} = U_c^i(U^j - V^j) + U_c^j(U^i - V^i) - \lambda P_c = 0 \qquad \text{(A3.5a)}$$

$$\frac{\partial L}{\partial L^i} = U_{L^i}^i(U^j - V^j) - \gamma^i = 0 \qquad \text{(A3.5b)}$$

$$\frac{\partial L}{\partial F^i} = \lambda P_q Q_{F^i} - \gamma^i + \sigma^i = 0 \qquad \text{(A3.5c)}$$

$$\frac{\partial L}{\partial M^i} = \lambda W^i - \gamma^i + \varphi^i = 0 \qquad \text{(A3.5d)}$$

$$\frac{\partial L}{\partial X} = \lambda(P_q Q_x - P_x) = 0 \qquad \text{(A3.5e)}$$

$$\frac{\partial L}{\partial \lambda} = [P_q q(F^m, F^f, X; \xi) - P_x X] + W^i(M^m + M^f) + I^m + I^f - P_c C = 0 \qquad \text{(A3.5f)}$$

$$\frac{\partial L}{\partial \gamma^i} = T^i - L^i - F^i - M^i = 0 \qquad \text{(A3.5g)}$$

$$\sigma^i F^i = 0 \qquad \text{(A3.5h)}$$

$$\varphi^i M^i = 0 \qquad \text{(A3.5i)}$$

Where $i \in \{m, f)$ and $i \neq j$

From equations (A3.5a) and (A3.5b), the marginal rate of substitution for consumption (C) and leisure (L^i) is specified as:

$$\frac{U^i_{L^i}(U^j - V^j)}{U^i_c(U^j - V^j) + U^j_c(U^i - V^i)} = \frac{\gamma^i}{\lambda P_c} \qquad \text{(A3.5j)}$$

The implication of equation (A3.5j) is that the marginal rate of substitution between the male's leisure and consumption is equal to that of female and is equal to the ratio of their prices. From equations (A3.5c) and (3.5d) we can solve for γ^i

$$\gamma^i = \lambda P_q Q_{F^i} + \sigma^i \qquad \text{(A3.5k)}$$

$$\gamma^i = \lambda W^i + \varphi^i \qquad \text{(A3.5l)}$$

Upon combining with equation (A3.5j) we obtain

$$\frac{U^i_{L^i}(U^j - V^j)}{U^i_c(U^j - V^j) + U^j_c(U^i - V^i)} \geq \frac{W^i}{P_c} \qquad \text{(A3.5m)}$$

$$\frac{U^i_{L^i}(U^j - V^j)}{U^i_c(U^j - V^j) + U^j_c(U^i - V^i)} \geq \frac{P_q Q_{F^i}}{P_c} \qquad \text{(A3.5n)}$$

From the first order conditions, there exist three possible scenarios for household farm and off-farm labor allocation.

i) When $M^i > 0$ and $F^i > 0$; and from equation (A3.5h) and (A3.5i) $\varphi = 0$, $\sigma = 0$, then $W^i = P_q Q_{F^i}$. The implication of this is that individuals will participate both in farm and off-farm activity when the market wage is equal to the marginal value of farm production. The optimal condition for the allocation of consumption and time is specified as:

$$\frac{U^i_{L^i}(U^j - V^j)}{U^i_c(U^j - V^j) + U^j_c(U^i - V^i)} = \frac{W^i}{\lambda P_c} = \frac{P_q Q_{F^i}}{P_c} \qquad \text{(A3.5o)}$$

ii) When $M^i = 0$, and $F^i > 0$; $\varphi \geq 0$, then $W^i < P_q Q_{F^i}$. This implies that individuals will allocate more labor time to farm work when the returns to farm work is greater that market wage.

iii) when $M^i > 0$, and $F^i = 0$; $\sigma \geq 0$, then $W^i > P_q Q_{F^i}$. This implies that individuals will allocate more labor time to off-farm work than farm work. Thus equation (A3.5n) holds with equality while (A3.5m) does not.

Table A9: Distribution of Household Food Security Indicators

		Occurrence		Frequency of occurrence		
		Yes	No	Rarely	Sometimes	Often
A	**Domain: Anxiety and Uncertainty**					
1	Did you worry that your household would not have enough food?	79.60	20.40	37.68	26.97	3.45
B	**Domain: Insufficient Quality**					
2	Were you or any household member not able to eat the kinds of foods you prefer because of lack of resources?	72.91	27.09	37.44	29.06	6.40
3	Did you or any household member eat just a few kinds of food day after day due to lack of resources?	69.70	30.30	37.07	27.96	4.68
4	Did you or any household member eat food that you preferred not to eat because of lack of resources to obtain other food types?	66.26	33.74	38.42	24.63	3.20
C	**Domain: Insufficient Quantity**					
5	Did you or any household member eat a smaller meal than you felt you needed because there was not enough food?	58.00	42.00	34.48	20.44	3.08
6	Did you or any household member eat fewer meals in a day because there was not enough food?	51.60	48.40	32.76	16.63	2.22
7	Was there ever no food at all in your household because there were no resources?	22.41	77.59	15.76	5.67	0.99
8	Did you or any household member go to sleep at night hungry because there was not enough food?	21.43	78.57	15.39	4.80	1.23
9	Did you or any household member go a whole day without eating anything because there was not enough food?	20.44	79.56	14.78	5.05	0.62

Table A10: Results of PCA: Varimax rotation factor matrix

Variable	Comp1	Comp2	Unexplained
FIQ1	0.341	0.060	0.364
FIQ2	**0.468**	-0.104	0.173
FIQ3	**0.462**	-0.076	0.151
FIQ4	**0.433**	-0.035	0.197
FIQ5	0.392	0.054	0.189
FIQ6	0.331	0.130	0.262
FIQ7	0.031	**0.534**	0.187
FIQ8	0.008	**0.584**	0.100
FIQ9	-0.012	**0.577**	0.168
Variance	4.625	2.584	
Percent variance explained	0.514	0.287	

Table A11: Maximum Likelihood estimates of IV Ordered Probit Model

	Food Insecurity		Empowerment	
Variable	Coef.	Std. Err.	Coef.	Std. Err
Empowerment score	-2.7370***	0.7761		
Age (years)	-0.0037	0.0058	0.0009	0.0054
Education (years)	-0.0615***	0.0246	0.0074	0.0220
HH size (no. of persons)	0.0629**	0.0259	0.0483**	0.0232
Marital status (Married=1)	-0.0529	0.1699	0.1724	0.1594
Plot size (ha)	-0.0693**	0.0361	0.0037	0.0234
Livestock ownership (TLU)	0.1225	0.1778	0.3714**	0.1600
Intercropped (yes=1)	0.1831	0.2374	-0.3678*	0.2208
Agric is main occupation	-0.0260	0.1950	0.0545	0.1980
Adopt SCT (yes=1)	0.0493	0.2986	0.3416	0.2855
Received extension services (yes=1)	0.0715	0.1497	0.0480	0.1348
Plot manager (yes=1)	0.3539	0.3317	1.1664***	0.3152
Adopt improved variety (yes=1)	0.1052	0.3383	1.0141***	0.2945
Fertile soil (yes=1)	-0.7051***	0.2005	-0.2314	0.1962
Poor soil (yes=1)	-0.2299	0.2149	-0.1904	0.2361
Deep plot depth (yes=1)	-0.1282	0.2241	0.0289	0.2712
Shallow plot depth (yes=1)	-0.3123*	0.1840	-0.2685*	0.1566
Region (Western =1; Eastern=0)	-0.3847**	0.1943	-0.5670***	0.1770
Instrument				
participation in any community activities in the previous year (yes=1)			1.3125***	0.4959
/atanhrho_12	0.5911***	0.1839		
/cut_1_1	-3.1944***	0.6603		
/cut_1_2	-1.8824***	0.6827		
/cut_2_1	-0.8073	0.9112		

/cut_2_2	-0.4745	0.9152
/cut_2_3	0.5540	0.9249
/cut_2_4	0.8869	0.9320
/cut_2_5	1.4500	0.9445
/cut_2_6	1.5190	0.9468
/cut_2_7	2.0465**	0.9479
/cut_2_8	2.6283***	0.9514
/cut_2_9	2.7599***	0.9541
/cut_2_10	3.6975***	0.9700
rho_12	0.5307	0.1321
Observations	259	
Log pseudolikelihood	-709.14526	
Wald chi2(18)	70.12	
Prob > chi2	0.0000	

Robust standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1