TOWARDS AGRICULTURAL TRANSFORMATION: FACTORS INFLUENCING THE CULTIVATION OF HIGH VALUE AGRICULTURAL PRODUCTS IN UGANDA

By

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Declaration

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ABSTRACT

Growing global markets have created opportunities that much of sub-Saharan Africa has been leveraging through the expansion of export diversification. The share of high-value agriculture (HVA) in total exports out of sub-Saharan Africa has increased from 8.4% in 2001 to 10.2% in 2016, although it is believed this is far beneath SSA’s true potential. The emergence of domestic and international markets for high value agricultural products presents a real opportunity for growth and development, specifically for smallholder famers by providing increased economic returns and marketing opportunities. It is becoming widely recognized that various development indicators can improve if smallholder farmers are better integrated into these markets. Using Ugandan household panel data, this study seeks to understand the factors related to the decision to cultivate HVA and the households’ marketing outcomes. A triple-hurdle model is employed to robustly examine market-related decisions made by smallholder farmers beyond common approaches to market participation models. Results indicate that policies that encourage HVA market participation simultaneously increase the likelihood of non-producers of HVA to commence producing and lead to greater levels of net sales in the market. Furthermore, HVA producers have greater likelihoods associated with being net sellers in the market.

Uittreksel

Groeiende internasionale markte het geleenthede vir ŉ beduidende gedeelte van Afrika suid van die Sahara (SSA) geskep, hierdie is deur die groei in uitvoer diversifikasie versterk. Die aandeel van hoë-waarde landbou (HWL) uitvoere in totale uitvoere in SSA het tussen 2001 en 2016 van 8.4% tot 10.2% gestyg, maar sommiges is steeds van mening dat hierdie onder die streek se potensiaal is. Die totstandkoming van plaaslike en internasionale markte vir HWL produkte bied ware geleenthede vir groei en ontwikkeling, spesifiek vir kleinboere deur die skep van ekonomiese- en bemarkingsgeleenthede. Dit is nou alombekend dat verskeie ontwikkelingsaanduiders verbeter kan word indien kleinboere beter met markte geïntegreer word. Hierdie studie gebruik ŉ Ugandese huishoudelike-paneeldatastel om huishoudings se besluit om HWL produkte te produseer beter te verstaan en die bemarkingsuitkomste daarvan te kwantifiseer. In teenstelling met die meer algemene markdeelname-benadering gebruik hierdie studie ŉ driedubbele-versperringsmodel om die markverwante besluite van kleinskaalse boere op meer robuuste wyse te ondersoek. Die resultate dui aan dat die beleid wat HWL mark deelname aanmoedig beide die waarskynlikheid van HWL produksie onder nie-HWL kleinboere verhoog en tot hoër netto mark verkope lei. Verder het HWL produsente ook ŉ groter waarskynlikheid om met netto verkopers in die mark geassosieer te word.

Dedication

This thesis is dedicated to my parents, Connie Currier, Thomas Jayne and Kimm Jayne

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List of Abbreviations

Average Partial Effect	**(APE)**
High Value Agriculture	**(HVA)**
Inverse Mills Ratio	**(IMR)**
Kilometer	**(Km)**
Maximum Likelihood estimation	**(MLE)**
Meters Above Sea Level	**(MASL)**
Millimeter	**(mm)**
Sub-Saharan Africa	**(SSA)**
Ugandan Shillings	**(UGX)**

CHAPTER 1: INTRODUCTION

Agriculture is recognized as the key sector to drive broad-based economic development across sub-Saharan Africa. As such, the Comprehensive African Agriculture Development Plan (CAADP) is a re-commitment by African Leaders to accelerated agricultural growth and transformation. Under the Malabo Declaration in 2014, African policy-makers set the target of halving poverty by 2025 through targeted commodity-specific policy interventions that would drive inclusive transformation (AUC, 2014). Evidence of structural change for the economy as a whole is proven to be catalyzed from within the agricultural sector for many lesser developed countries (Shilpi and Emran 2016). Thus, to meet the objectives put forth by African leaders in CAADP, it is imperative that we advance our policy maker's understanding of the factors associated with the decision of which crops to cultivate.

Smallholder farmers in much of sub-Saharan Africa cultivate a narrow range of crops with low economic returns. The emergence of domestic and international markets for high value agricultural products presents a real opportunity for growth and development, specifically for smallholder famers by providing increased economic returns and marketing opportunities. The share of high-value agriculture (HVA) in total exports out of sub-Saharan Africa has increased from 8.4% in 2001 to 10.2% in 2016, although it is believed this is far beneath SSA's true potential. Policies supporting crop diversification could be a catalyst for – and are at least necessary for agro-economic structural transformation that is known to accompany long-run economic growth and poverty reduction.

Using Ugandan household panel data, this study seeks to understand the factors related to the decision to cultivate HVA and the households' marketing outcomes using a triple hurdle model developed by Burke et al. (2015). Results indicate that policies that encourage HVA market participation simultaneously increase the likelihood of non-producers of HVA to commence producing and lead to greater levels of net sales in the market. Furthermore, HVA producers have greater likelihoods associated with being net sellers in the market.

1.1 Structural Transformation

Historically, agriculture has played a changing role in the broader theories of economic structural transformation. Agricultural transformation can be described as "*the process by which an agrifood system transforms over time from being subsistence-oriented and farm-*

centered into one that is more commercialized, productive, and off-farm centered." (AGRA, 2016). The classic models of structural change and economic growth with respect to Lewis (1954), Kuznets (1973) and Timmer (1988) observe a declining share of agriculture in a nation's employment and GDP as a key feature of economic development and poverty reduction (Alvarez-Cuadrado, 2011; Shilpi and Emran, 2016). Schultz (1953) states that improved agricultural productivity is a necessary precondition for an industrial revolution since increases in agricultural productivity raise per capita incomes, in turn generating demand for non-farm activities (Ranis and Stewart, 1973; Mellor, 1976; Haggblade, Hazell and Reardon, 2006; Alvarez-Cuadrado, 2011; Shilpi and Emrann, 2016). This sectorial reallocation of resources is driven by Engel's law, where greater per capita incomes from increased agricultural productivity transfer labor from agriculture into other sectors of the economy (Alvarez-Cuadrado and Poschke, 2011). The phenomenon of factor shifts out of agriculture has played an important role in stimulating the process of agricultural and economic transformation. Various researchers have sought to decompose these drivers on a finer scale.

Five "interlinked" steps of agrifood transformations in the context of agricultural transformation have been identified in Asia and are emerging in Africa. In Timmer's (1988) The Agricultural Transformation, he states that the evolving stages of an economy take a remarkably uniform process across different countries, which manifest within the agricultural sector. The steps include (1) urbanization; (2) diet change (3) agrifood system transformation; (4) rural factor market transformation; (5) intensification of farm technology (Johnston and Mellor, 1961; Ranis et al., 1990; Delgado et al., 1994; Timmer, 2002). These represent, in macro terms, the fundamental drivers that occur as an economy becomes more modernized.

The occurrence of rural to urban migration and urbanization is accompanied by lifestyle changes. Through Bennet's Law (Bennet 1954), when incomes rise, so does the desire for a diversified diet, which can lead to changes in the product composition of demand (Reardon and Timmer 2014). Typically, this can have several outcomes, which include growing demand for meats, dairy products, fruits and vegetables, feed grains and vegetable oils, processed foods for home cooking; and prepared foods consumed away from home, while experiencing a shift away from cereals. Diversified diets may be a signal of crop diversification if those crops are sourced domestically. However, Dawe (2015) points out that dietary diversity at the national level need not imply crop or production diversity, because international trade may be meeting domestic consumer demand for diverse products. Crop diversification at the national-level is often determined to a large extent by the country's agro-ecological zones suitable for a broad range of crops, as well as its market development and stage of agricultural transformation (Kurosaki 2003; Dawe 2015; Rao et al. 2006). Contrarily, increased domestic demand for diverse products will serve as a catalyst for product diversification if the region is suitable for those crops being demanded and market conditions are conducive for such enterprises.

As the demand for a diverse range of goods incentivizes the sourcing of domestic products, local supply chains transform, this development has taken the overarching term, "supply-chain revolution" (Dawe 2015). Its process has been observed in two ways, first, as a "Modern Revolution" via developments of large scale retail and second stage processing growth. Secondly, as a "Quiet Revolution" which is catalyzed by small and medium-scale farmers at the first-stage of processing and the provisioning of upstream agricultural services (Reardon and Timmer 2007; Reardon et al. 2012a). To a large extent, these developments have been fueled by increased incomes, urbanization, the participation of women in labor markets, the onset of new processing technologies, and food diversification encouraged by the retail sector (Gehlhar and Regmi 2005).

Subsequently, the availability and accessibility of factor markets to smallholder farmers make the production of a diverse range of products possible. The rise of rural factor markets and non-farm employment is a response to market growth and changing diets via urbanization (Reardon and Timmer 2014). Rural factor markets include various on and off-farm actors in the supply chain such as processors, wholesalers, transportation services, credit markets, chemicals and machinery, among others. Their presence is integral in facilitating the upstream linkages in the supply-chain which contributes to greater levels of off-farm employment.

If the leaders of sub-Saharan Africa are committed to achieving transformation, then one of the elements that warrants significant attention is the decision of which crops to cultivate. Consistent with seminal definitions of crop diversification, a shift of resources from low value agriculture to high value agriculture (Hayami and Otsuka, 1992; Vyas, 1996) must occur. The progression of crop diversification is argued to not be limited only to production processes, but changing marketing and commercially based activities that expand income sources of smallholder farmers and grow the overall rural economy. Thus, crop diversification can be an indicator of agricultural transformation as smallholder farmers become more commercially oriented, as they shift away from staple, low-value agriculture to higher valued crops.

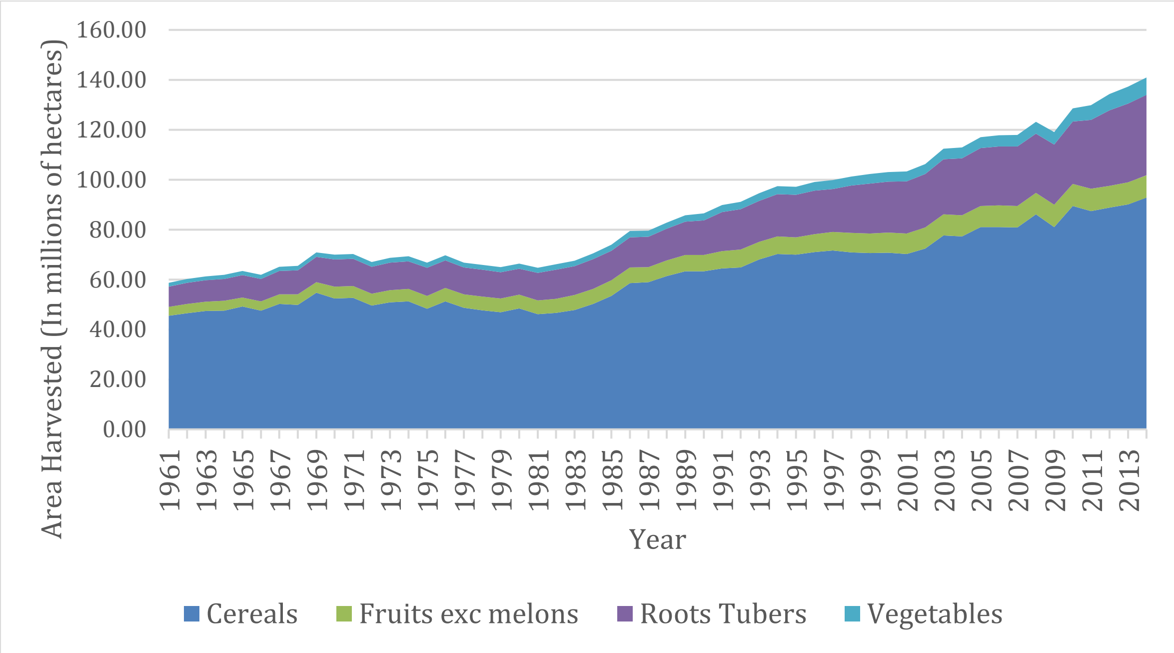
The extensive body of literature on economic growth and agricultural transformation (Reardon and Timmer 1988; Minot 2006; Gollin 2002; Kurosaki 2003; Ray 2010; Alvarez-Cuadrado 2011) [1] contends that diversified enterprises play an important role in these processes of agricultural transformation. Changes in land productivity are structurally related to the reallocation of land use among different crops (Kurosaki 2003). Therefore, to improve agricultural productivity, it is paramount to advance policy-maker's understanding of the factors that influence a farmer's decision of which crops to cultivate.

1.2 Regional Patterns of Land Use and Crop Diversification

To date, staple crops, predominantly cereals, dominate small-scale farmers' area harvested in Africa. Figure 1.1 illustrates the total area harvested in millions of hectares for cereals, roots and tubers, fruits (excluding melons) and vegetables in sub-Saharan Africa (SSA), from 1961-2014.

[1] Timmer, Peter C., "The Agricultural Transformation," in "Handbook of Development Economics," Vol. 1, Amsterdam and New York: North Holland, 1988, chapter 8, pp. 275–331. Ray, Debraj, "Uneven Growth: A Framework for Research in Development Economics,"Journal of Economic Perspectives, 2010, 24, 45–60. Gollin, Douglas, Stephen L. Parente, and Richard Rogerson, "The Role of Agriculture in Development," American Economic Review, Papers and Proceedings, 2002, 92, 160–164. Alvarez-Cuadrado, Francisco, and Markus Poschke. "Structural change out of agriculture: Labor push versus labor pull." *American Economic Journal: Macroeconomics* 3.3 (2011): 127-158. Kurosaki, Takashi. "Specialization and diversification in agricultural transformation: the case of West Punjab, 1903–92." *American Journal of Agricultural Economics* 85.2 (2003): 372-386.

Figure 1.1: Total Area Harvested in SSA: Disaggregated by Crop Category



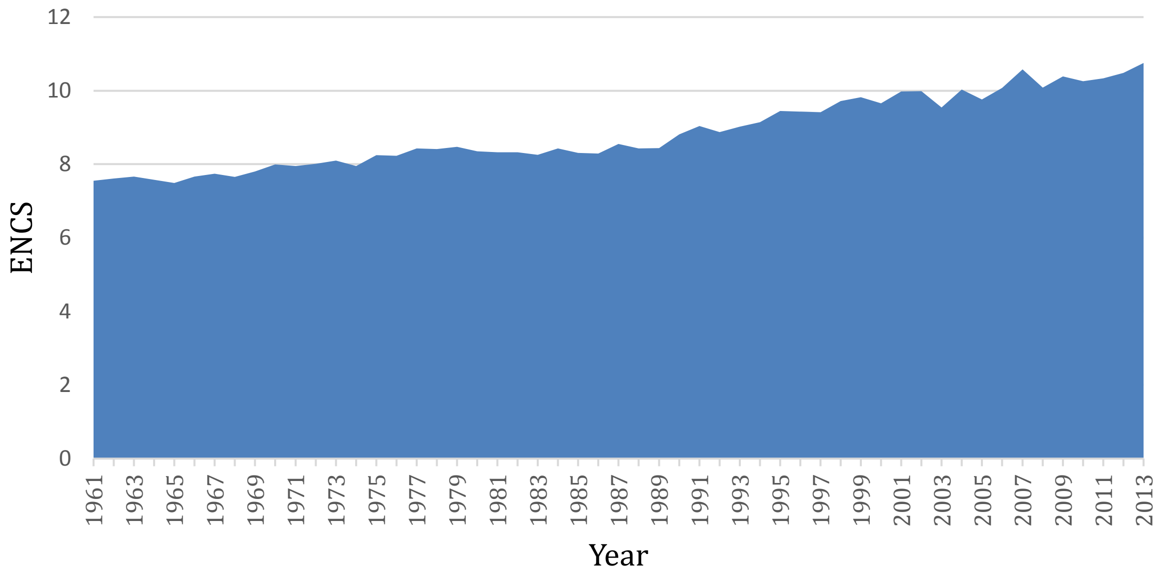
Source: FAOSTAT 2017. Author's own calculations

The share of cereals in total area harvested over the time period declined from 33.2% to 31.7%; tubers increased 6.1% to 7.0%; fruits increased from 3.2% to 3.6%; vegetables 0.9% to 1.6%. In staple cereal production, yields can be variable and capital intensive while gross profits are low (Davis 2006). In 2012, the Kenyan agricultural minister described the situation of small-scale farmers saying, "Our farmers need to diversify their activities and venture into horticultural farming instead of relying on maize and wheat where earnings are low" (Kosgei 2012). This point reinforces that more smallholder farmers will grow their earnings if they shift away from staples to higher valued crops.

Despite low levels of crop diversity at the continental level, crop diversity has been trending upward in many sub-Saharan Africa countries, but at a slow rate. Figure 1.2 below illustrates the state of play of eight countries in the region with regards to crop diversification. The Shannon Diversity Index, expressed as the Effective Number of Crops Species (ENCS), is an index for diversification that collectively includes eight sub-Saharan African countries from 1961-2013. The value of the index represents an estimate for the number of crop species dominating production in the specific areas within sub-Saharan Africa. An increase of 42.3% is realized over the past 50 years, showing a shift in the score from 7.55 to 10.75 which indicates a substantial rise in the number of dominant crops under cultivation. In the early

1990's there is a perceivable increase in the ENCS score, as compared to previous decades. Notwithstanding this upward trend, there remains great opportunity to increase crop diversity.

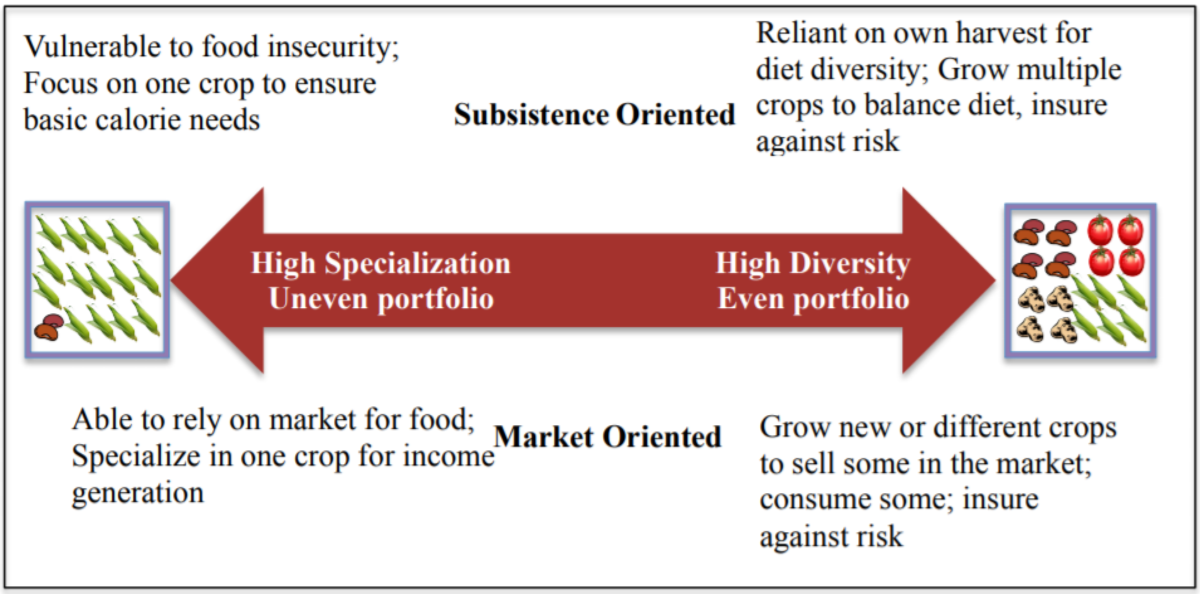
Figure 1. 1: Effective Number of Crop Species for Select Countries in SSA



(Countries include the Democratic Republic of the Congo (DRC), Malawi, Mozambique, South African Tanzania, Uganda, Zambia and Zimbabwe)
Source: Bureau for Food and Agricultural Policy (2016)

From a farmer's perspective, the decision to diversify their crop mix is theoretically based on a series of opportunities and threats, while controlling for other factors. Opportunities largely stem from changing consumer demand, urbanization, export potential, and marketing opportunities, to name a few (Krishi 2011). Strategies that address threats may include a diversified crop portfolio to hedge against various risks, such as crop price and yield fluctuations due to the effects of climate change or pests, among other variables. Additionally, smallholder farmers might diversify to meet home consumption demand, then sell their surplus in the market for added income. Such decisions can be wide-ranging and a host of factors can play a role. Below, figure 1.3 provides an abstraction from Turner (2014), which illustrates the different orientation that small-scale farmers may choose based on these characteristics and their level of development.

Figure 1.2: Production Orientation Options for Smallholder Farmers



Source: Turner 2014

1.3 Purpose of the Study and Research Questions

Limited research has made the link empirically between the decision to cultivate high value agriculture (HVA) and marketing outcomes. Burke et al. (2015) implements a triple-hurdle model that is the first of its kind to appropriately address such a research question for dairy production. This method is used to examine whether policies encouraging market participation may also induce non-producers of a good to commence production. Furthermore, it allows the researcher to determine what factors influence the probability of an agricultural household being a net-seller in the market, conditional on being a producer of a given product of bundle of products. The value of using this methodology permits the researcher to draw broader conclusions around the impact of policies that are aimed at promoting market participation of smallholder farmers. It allows us to determine whether policies aimed at facilitating market participation may have further reaching impacts on smallholder welfare than prior research may have suspected. This is because policies believed to promote market participation may also induce smallholders to start cultivating HVA. A triple hurdle model is especially appropriate for goods that are less frequently produced by the general population, such as HVA or dairy, for example.

Research Questions

If increased agricultural productivity, be it yields or growing rural incomes, is considered a key indicator of agricultural transformation, this study argues that empirically, the cultivation of higher valued agricultural products by smallholder farmers is an important factor in this process. The importance of HVA is relevant since farmers who cultivate HVA are believed to have greater likelihoods of becoming more commercially oriented, likely to sell greater quantities in the market. Recently, the government of Uganda has implemented an array of initiatives to promote smallholder commercialization and agricultural diversification. In the past two decades, access to information on technology adoption and crop-specific training from extension services should have particular relevance in encouraging a shift away from staples to higher valued agriculture, which are expected to be significant determinants in this study (Barungi et al. 2016; Komarek 2010).

The research objectives and hypotheses borrow Bill Burke et al. (2015) triple hurdle model and use Uganda panel data from the Living Standards Measurement Study (LSMS) to examine:

- What are the determinants of smallholder production of HVA
- What are the factors that determine whether a HVA producing smallholder is a net buyer, autarkic, or net seller in the market
- How do these determinants affect the degree of market participation, or quantities bought and sold, among participants?

This research hypothesizes that:

- Access to information, infrastructure, inputs, capital, and crop prices, are significant determinants of HVA cultivation and market participation,
- The same processes that influence a farmer to cultivate HVA increase the probability of being a net seller in the market

The triple-hurdle model allows for a more comprehensive analysis of how selected factors influence farming and marketing decisions for a particular product beyond methods that have been used before. The analyses control for household and district-level characteristics that are widely cited factors which influence agricultural household decisions. Conventional wisdom posits that these factors include but are not limited to household demographics, capital and assets ownership, agro-ecological, crop prices and district-level features.

Chapter Two provides a glimpse into the historical context of Uganda along with a smallholder overview, then proceeds with a literature review of crop diversification, the empirical framework for the estimations, its results and conclusions.

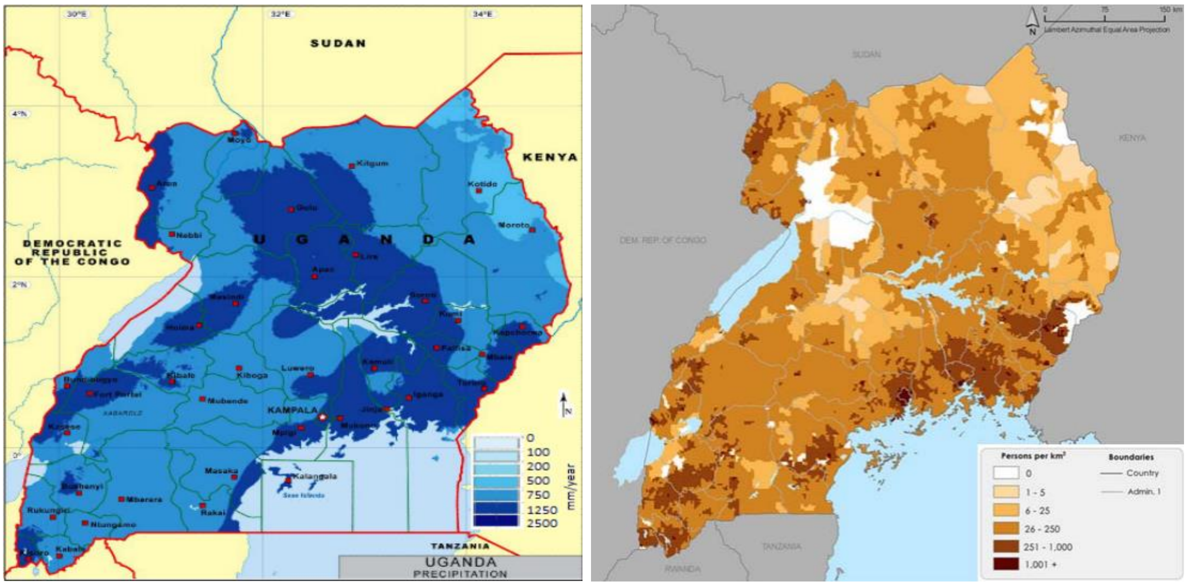
CHAPTER 2: THE UGANDAN CONTEXT

2.1 Geographical Context

Located in the Rift Valley of Eastern Africa, Uganda sits in an area of semi-arid savannah, bush and mountains (Quam 1997). Uganda is landlocked and densely populated with 206.9 people per square kilometer (World Data Atlas 2016). Today its total population is approximately 41.49 million and is comprised of a cluster of various ethnic groups, many which belong to the Bantu family (Worldometer 2017).

Its climate is mostly equatorial and rainfall and temperatures can vary drastically by region. Southern and south-west Uganda generally experience consistent rainfall throughout the year, while the north-east is dry and drought prone (Haggblade 2010). Rainfall averages in the southern regions of the country are 1500 mm per annum and less than 500 mm in the northeast. Reports state erratic rainfall is believed to be associated with climate change and making the distribution of rainfall more volatile and uneven, with some heavy rainfall events (NEMA 2010). Uganda's climate and agro-ecological features are favorable for agriculture and has been called a high-performing region despite its regional susceptibility and proneness to drought (Masih et al. 2014; Leliveld et al. 2013). A large area of Uganda consists of high elevation plateau, ranging from 1000 and 2500 meters above sea level (Ronner and Giller 2013). Figures 2.1 below depicts the average annual rainfall in millimeters and population density across Uganda.

Figure 2.1: Rainfall (mm) and Population Density (Km Squared)



Source: NASA, 2000

The northern regions of the country experience unimodal rainfall and annual crops such as maize, sorghum, groundnuts and sesame dominate. In the southern parts where it is bimodal, the most common are perennial crops which include banana and coffee (Mubiru et al. 2012). Uganda's climate and agroecological zones are conducive to horticulture and has had much success with cash crops, such as coffee, cocoa, tea, and flowers among others.

Most of its population coincides with areas of greater higher annual rainfall averages. The central region of Uganda contains approximately 50% of its total population, nearing Lake Victoria, as can be seen in 2.1.

2.2 Historical and Economic Context

Historically, there has been significant competition amongst various ethnic clans, much of which has been over pasture and scarce natural resources such as water, livestock, and land. Livestock rearing and its accumulation have significant cultural, economic and symbolic ties in Uganda. Cattle husbandry is customary among men, and thus pastoral lands are of significant cultural importance. Competition for land, water, forest products and mineral resources have been a persistent trigger for inter-community and ethnic violence (Minority Rights Organization 2011).

Uganda's economic modernization and development has been accompanied by a series of civil conflicts following independence. Economically, its history has been bleak, plagued by cycles of famine until the early 1990's, and has experienced less frequent, but still recurrent food insecurity even until today. Recently, Uganda has become more peaceful and increasingly stable with significant overall progress socially and economically (Minority Rights Organization 2011). Table 2.1 provides a small summary of some of Uganda's social and economic statistics.

Table 2.1: Economic Overview for Uganda: 2017

Climate	Tropical; semi-arid in northeast
Population:	41,699,654 (Worldometer 2017)
Age Structure:	
0-14 years:	48.26% (male 9,223,926/female 9,268,714)
15-24 years:	21.13% (male 4,010,464/female 4,087,350)
25-54 years:	26.1% (male 5,005,264/female 4,997,907)
55-64 years:	2.5% (male 460,000/female 496,399)
65 years and over:	2.01% (male 337,787/female 431,430) (2016 est.)
Urbanization	
Urban population:	16.1% of total population (2015)
Fertility	
Total Fertility Rate	5.8 children born/woman (2016 est.)
Sanitation Access	
(Improved)	
Urban:	28.5% of population
Rural:	17.3% of population
Total:	19.1% of population
(Unimproved)	
Urban:	71.5% of population
Rural:	82.7% of population
Total:	80.9% of population (2015 est.)
Literacy	
Definition:	age 15 and over can read and write
Total population:	78.40%
Male:	85.30%
Female:	71.5% (2015 est.)
Demographics	
Population Growth Rate:	3.3% annually (World Bank)
Life Expectancy:	59.18 (World Bank)
Economy	
GDP Growth Rate:	4.9% (2016 est.)
Agriculture:	24.50%
Industry:	21%
Services:	54.4% (2016 est.)
GDP Purchasing Power Parity:	$84.93 Billion (2016 est.)
GDP per capita:	$2,100 (2016 est.)

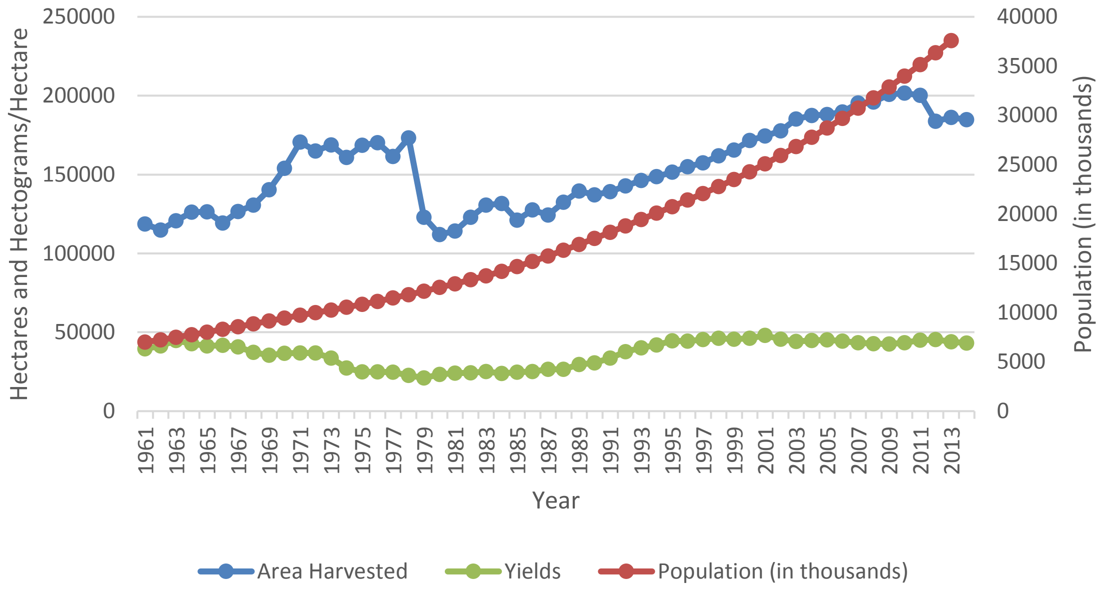
Sources: CIA World Factbook, Worldometer, World Bank

With regards to agriculture, Uganda presents a fascinating case for study because it has abundant natural resources. However, the country is faced with various problems that are hindering the growth of the agricultural sector such as declining soil fertility, drought and lack of proper investment in key areas that promote agriculture (FAOstat 2017).

Like many other African countries, agriculture is the primary sector of the economy. Numerous sources have identified Uganda as having a wealth of natural resources and agricultural potential. Up to 80% of Uganda's land is arable, although it is estimated that only 35% is being cultivated (FAOstat 2017). The share of agricultural production in total GDP has declined over the past years, while its growth in the sector has remained around 2.6% per annum in the past eight years (World Bank 2016). Agricultural growth has been largely hindered by supply-side constraints such as inadequate investments in a sector that continues to depend on low levels of technology. There exists enormous potential in agro-processing, although it has been relatively untapped (World Bank 2016). The sector still comprises 24.5% of the nation's GDP in 2015 (World Bank, 2017), employs approximately 80% of the labor force in 2016 (FAO 2016) and accounts for 85% of export revenues (World Bank, 2017; USAID, 2016). Additionally, in 2010 agriculture contributed to approximately 40% of the manufacturing sector via food processing (NEMA 2010).

In Uganda's colonial era, the British did not develop large-scale plantations with the exception of tea and sugar estates, and later implemented cotton and coffee as a "forced system of cultivation" (Leliveld et al. 2013: 422-3). Production of cotton and tea practically collapsed during the 1970's. The government attempted to promote diversification in commercial agriculture that would broaden a variety of non-traditional exports (Chauvin et al. 2017). Coffee became the primary export crop during the late 1980's and has remained until recently despite its decline of up to 17.9% of total export earnings. Data from FAO illustrates Uganda's agricultural productivity from 1961 to 2011 in figure 2.2. Much of the productivity gains have been achieved through area expansion while lesser improvements from yields, especially since the 1980's. Over the time period, agricultural production has not kept up with population growth. Population growth is over five times in 2013 of what it was in 1961; area harvested grew approximately 50% over the time period; and yields have stagnated since the 1980's.

Figure 2.2: Uganda Production, Yields and Population Trends



Source: FAOSTAT 2017. Data includes all reported crops

Ugandan agricultural commercialization has been a key policy topic to break the stagnation in agricultural productivity. Broad economic growth in Uganda is envisioned to take place with large improvements in the agricultural sector, since other economic sectors are still in phases of low development (Dorosh and Thurlow 2009).

2.3 Smallholder Farming

The majority of agricultural output comes from 3 million smallholding subsistence farms with an average plot size of 2.5 hectares (FAO 2017). These smallholders constitute approximately 85% of the people engaged in agriculture, while medium scale and large scale constitute 12% and 3% respectively (DRT 2012). Smallholder farmers, whose definition is usually of a farmer with up to 10 hectares of land (FAO 2016) own approximately 92.1% of agricultural land in Uganda.

Table 2.2 provides a breakdown of the percentage of agricultural land under each landholding category, as well as the average number of crops cultivated on that type of farm size. Data is from the World Bank's Living Standards Livelihood Survey (LSMS) in conjunction with the Ugandan National Household Survey (UNHS).

Table 2.2: Share of Agricultural Land Owned by Farm-holding Size

Landholdings	Percentage of Land	Average Number of Crops Cultivated
Less than 1 Ha	*24.65%*	*3.59*
Between 1 and 5 Ha	*56.75%*	*4.78*
Between5 and 10 Ha	*10.70%*	*5.33*
Greater than 10 Ha	*7.90%*	*5.57*

Source: Uganda World Bank LSMS survey 2010/2011 and 2013/2014 *n= 2,032*

Farming in Uganda is predominantly rain-fed with use of low-cost inputs and is labor intensive. Farming systems can generally be characterized as mixed and intercropped. Many households combine plantains with cassava, millet, sorghum, sweet potatoes, beans, groundnuts or maize, sometimes including a cash crop such as coffee, cocoa or tobacco (Komarek 2010).

Infrastructure has remained undeveloped, especially in rural Uganda due to low investment levels compared to other countries in the region (World Bank 2012). Government expenditures in the agricultural sector were only 4-5% of the national budget from 2001-2008, despite intra-regional pledges in the Malabo Declaration to commit 10% (AUC, 2014). This has led to high input costs, low farm-gate prices, significant transaction costs and low levels of commercialization (World Bank 2012). Missing or underdeveloped food markets and perceived high uncertainty around price and yield are common disincentives to increase production (World Bank 2012). Considering relatively high prices of inputs, scarcity of food or insurance markets (absence and, or access), and yield risks, production for self-sufficiency takes priority for most households. Where markets are more developed and accessible allowing for higher and less volatile prices of non-staple crops, farmers in Uganda are more inclined to specialize in higher-valued crops. According to the World Bank, the bottom 25% of commercialized households only sell 4% of their agricultural produce in the market while the top 25% sell more than 50% of their total production.

2.3.1 Diet and Consumption

Ugandan household diets are largely dependent on staple commodities. Table 2.3 below illustrates the typical Ugandan diet. Plantains (cooking bananas), cassava, maize, sweet potatoes and beans dominate the consumption categories, although pulses, nuts and green vegetables also compliment the diet in smaller portions. Plantains, also called "matoke" or "matooke", have a distinct cultural connection to Uganda and plantains are considered the primary staple (Haggblade & Dewina 2010). The main staple crops are broken down into several consumption categories, where plantains, cassava and maize represent the bulk of caloric intake. Other sources have identified plantains and beans as the most important in consumption rankings, likely for nutritional reasons, despite beans ranking sixth in table 2.3 (Mulunba et al. 2012).

Table 2.3: Staple Food Consumption in Uganda

Commodity	Annual Quantity consumed kg/capita	Daily caloric intake kcal/day	Calorie share In Total Diet (percent)
Plantains	172	419	18%
Cassava	101	300	13%
Maize	31	266	11%
Sweet Potatoes	82	215	9%
Beans	16	148	6%
Wheat	7	42	2%
Rice	4	53	2%
Other		1133	48%
Total		2,360	100%

Source: Haggblade & Dewina, 2010

Three of the most important staple crops, plantains, cassava and sweet potatoes are relatively untraded in the export market. However, maize and beans are widely traded. Farmers usually produce a surplus of these crops which are traded within the region, mostly to Kenya who experiences consistent maize deficits, along with other countries in the EAC (Haggblade and Dewina 2010).

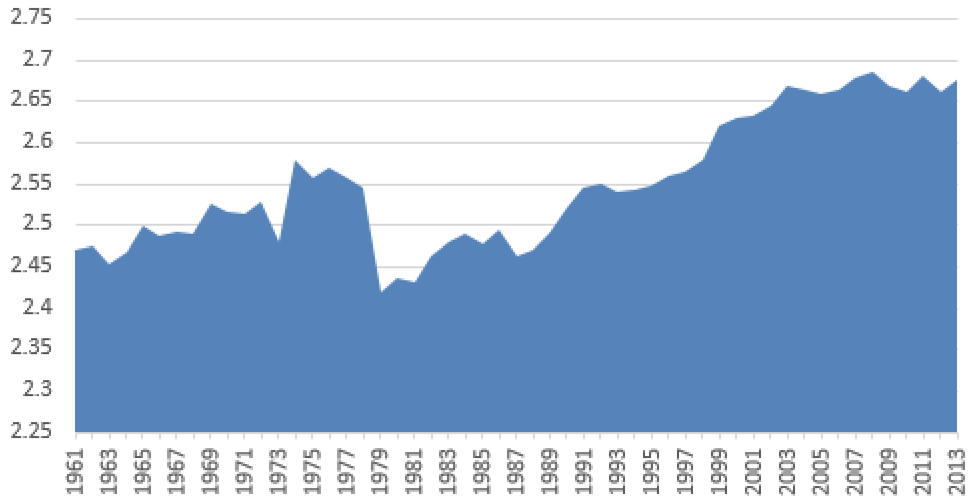
2.3.2 Agricultural Diversity

Various policies in the past two decades have promoted the commercialization of smallholder farms. With mixed results, success has mainly been seen in increased export for products that have values greater export values than $1,000 per ton. These products have been predominantly coffee, tea, cotton, flowers, and fish (World Bank 2012). Their value can sufficiently exceed farm-gate prices to make trading profitable despite high transactions costs. There has been lesser success for products with export prices below $1,000 per ton.

Uganda's top agricultural export products are coffee, raw tobacco, tea, maize and palm oil, with much of its market being Europe and neighboring African countries (OECD 2016). Since the 1980's, coffee has dominated the export base in Uganda. Despite it still being its primary export crop, there has been great diversification away from coffee in its export structure (OECD 2016). In the 1990's Uganda was one of the world's largest producers of coffee, which was an enormous contributor to GDP through exports, and played a significant role in rural incomes. Since the early 2000's, export prices for coffee dropped almost 70% and it became apparent that new export products would be needed to supplant coffee. Crop diversification to broaden the export market has since been a key objective, making Uganda a relevant case study. Uganda's mountainous landscape with high elevations can make diversification into some crops other than coffee a challenge. Even though Uganda remains a large coffee producer, other export products have begun to take its place, such as vanilla, tea, spices, fish and horticulture (Dunkley 2017).

To demonstrate the uptick in the production of new crops, figure 2.3 illustrates the Shannon Diversity Index (SDI). The SDI is an index commonly used to characterize the number of species within an area, it accounts for both abundance and equitable composition of the crops considered. In this case, we consider all crop species in aggregate for Uganda from 1961-2013. The SDI displays an approximately 8% increase in diversity over the past 52 years. A noticeable increase in the diversity score is apparent after 1990 when policies that promoted crop diversification and commercialization were implemented.

Figure 2.3: Shannon Diversity Index - Uganda

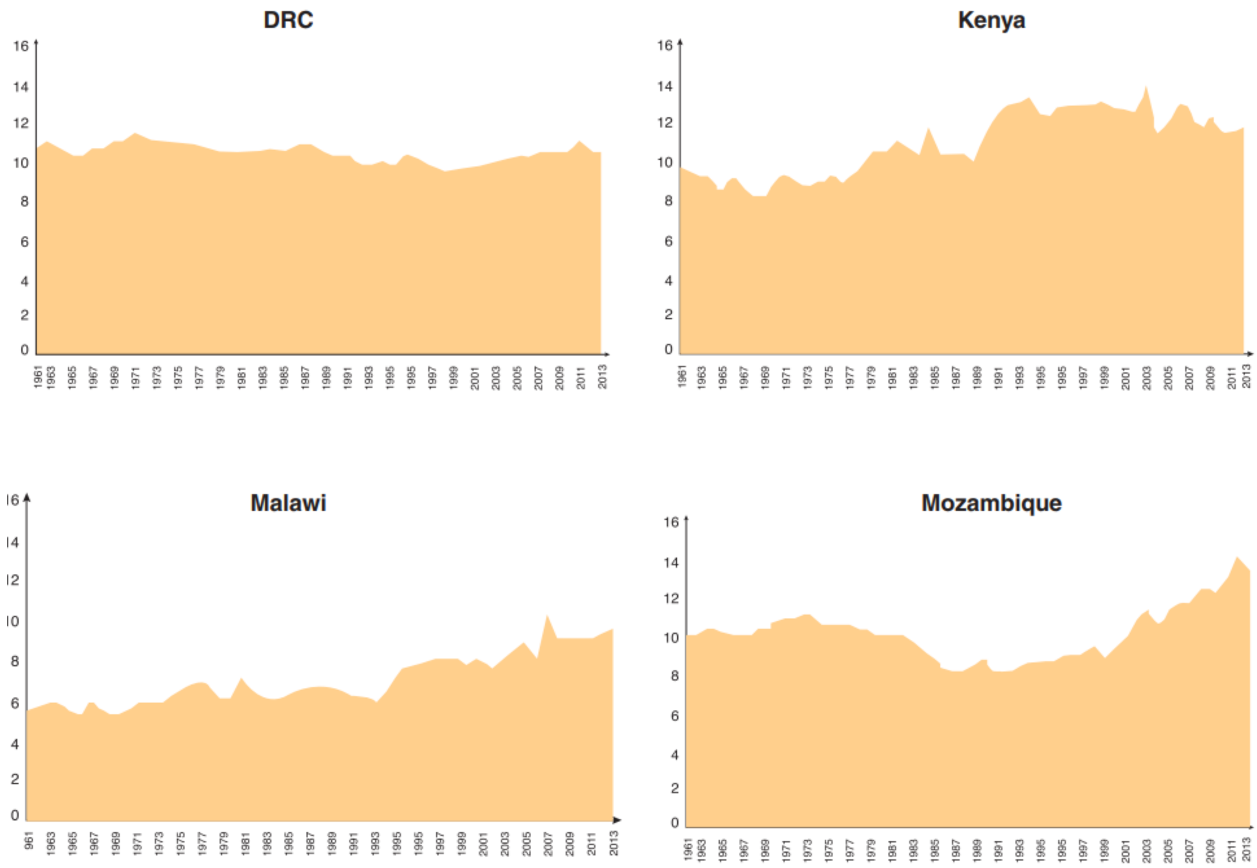


Source: Bureau for Food and Agricultural Policy (2016).

Contrasting Uganda with other countries within sub-Saharan Africa as seen in figure 2.4, Uganda exhibits a similar upward trend in diversity over the 52 year time span. Crop diversity may be associated with the transition from subsistence to commercialized farming, as smallholders could be shifting away from staple to higher valued crops (Africa

Agricultural Status Report (2016). Since many countries in SSA share the similar development challenges, insights to Uganda could be transferrable to other SSA countries with respect to factors that encourage crop diversity which could lead to increased commercialization.

Figure 2.4 Shannon Diversity Index – Select SSA Countries



Source: Africa Agricultural Status Report (2016)

Despite a gradual increase in crop diversity as indicated in the SDI among these various countries, impediments to smallholder crop diversification still remain. Many of the common challenges are lack of high-quality packaging, lack of storage facilities, high freight costs; a lack of road infrastructure in rural areas; a complicated and inefficient land tenure system; and a lack of specialized skills (NAADS, 2016; Export Gov, 2016). Proper infrastructural facilities that reduce transaction costs and facilitate market access are a key focal point to induce commercialization and diversification among smallholder farmers (Jaleta et al. 2009).

In Uganda's case, specialization is associated with areas of high levels of price and yield certainty (World Bank 2012). Most Ugandans are considered relatively diversified to account for such uncertainties. To demonstrate common levels of diversity among Ugandan farms, the Herfindahl-Hirschman index is another widely used tool to measure land concentration.

The index rises asymptotically toward one as a farmer's crop portfolio becomes increasingly specialized and toward zero with greater levels of crop diversity. The Herfindahl-Hirschman distribution for 75% of Ugandan farmers is below 0.27, which can be associated with approximately three different crops in their mix (World Bank 2012). Table 2.4 provides a breakdown of the household mean share of farmland allocated to the most common crops from 2009/2010 agricultural season to 2013/2014 to demonstrate typical smallholder land use.

Table 2.4: Household Mean Share of Agricultural Land Disaggregated by Crop

Crop	Land allocation	
	2009/2010	2013/2014
Cassava	16.95%	16.56%
Maize	15.89%	13.78%
Beans	11.40%	16.46%
Sweet potatoes	8.17%	6.31%
Banana food	7.12%	12.57%
Groundnuts	6.24%	6.47%
Sorghum	6.14%	3.19%
Coffee all	4.48%	0.70%
Finger millet	2.99%	2.50%
Sugarcane	1.70%	0.54%
Pigeon peas	1.56%	1.83%
Field peas	1.50%	0.39%
Simsim	1.19%	0.80%
Rice	1.10%	0.57%
Tobacco	1.09%	0.25%
Banana beer	0.84%	0.98%
Irish potatoes	0.51%	1.50%
Sunflower	0.41%	0.33%
Soya beans	0.37%	1.01%
Horticulture	3.93%	4.12%

Source: Uganda World Bank LSMS survey 2009/2010 and 2013/2014 $n = 2{,}032$

2.3.3 Farming Systems

Cassava and sweet potatoes are argued to be the most important crops of Uganda because of their importance for food security (Ronner and Giller 2013). Next in importance are plantains (cooking bananas), followed by coffee, maize and beans. The primary cereals produced are maize, finger millet, sorghum, rice, pearl millet and wheat (Kabeere and Wulff 2008). The major cash crops are coffee, cotton and tea.

Fermont et al. (2008) describes Uganda's farming systems as dynamic and constantly changing their strategies in response to increasing population densities and political and economic variables (Ronner and Giller 2013). For example, in parts of Uganda, cassava has frequently replaced cotton and millet as a method to reduce the negative impacts of soil mining. Or, fallows are usually rotated as part of a farming system, although with increasing population pressure, cassava is used an as "imitation fallow" in the case of poor fertility of soils to replenish nutrients (Ronner and Giller 2013). Table 2.5 illustrates the percentage share of farmers cultivating Uganda's primary crops, as well as the most frequently occurring crop portfolios from the 2010-2011 LSMS survey sample.

Table 2.5: Ugandan Crop Portfolios: 2010/2011

Crop	***Percentage of Households Cultivating***	***Common Uganda Crop Portfolios***	***Percentage of Households Cultivating***
Cassava	66.5%	Maize and Cassava	40.8%
Beans	61.1%	Maize and Beans	40.3%
Maize	60.0%	Cassava and Plantains	29.5%
Plantains	47.0%	Maize and Plantains	27.3%
Sweet Potatoes	44.6%	Maize and Sweet Potatoes	27.2%
Coffee	25.7%	Maize, Cassava, Beans	26.6%
Groundnuts	24.6%	Plantains and Coffee	23.0%
Sorghum	17.5%	Maize, Sweet Potato, Beans	19.3%
Horticulture	16.5%	Cassava, Coffee, Plantains	14.7%
Millet	12.0%	Maize, Plantains, Coffee	14.3%
Peas	8.7%	Maize, Coffee, Beans	12.9%
Irish Potatoes	4.0%	Maize, Plantains, Coffee, Beans	11.5%
Sesame	3.9%	Maize, Sorghum, Millet	3.0%
Cotton	1.8%	Maize and Tobacco	1.1%
Tobacco	1.5%	Cassava, Sorghum Tobacco	0.3%

Source: World Bank LSMS survey 2010/2011. Author's own calculations n = 2,126

Fresh fruits and vegetables are non-traditional export crops. In the 1980's horticulture production began to gain traction resulting from economic strategies to broaden the export base beyond its traditional exports coffee, cotton, tobacco and tea. Other non-traditional products beyond horticulture that have contributed to Uganda's growing export portfolio mainly include fish/fish products, floriculture, horticulture, spices, hides and skins, and honey (UNEP 2017).

Uganda is the second largest producer of horticultural products in sub-Saharan Africa after Nigeria. Its biggest export market is the European Union, primarily Belgium and the

Netherlands. 40% of horticultural production is from smallholder farmers indicating there is great potential to increase production.

Despite low intra-regional levels of trade for HVAs, increasing global consumption of these products has led to new marketing opportunities for producers. From 1961 to 2007, area harvested for fruits has increased 172.14% from 672,200 hectares to 1,829,370 hectares, however from 2007 to 2015, the area decreased 45.87% to 991,790 (FAOSTAT 2018). Vegetables have increased 10.29% from 54,907 hectares in 1961 to 60,562 hectares in 2015 (FAOSTAT 2017). These trends indicated that these products becoming gradually more prominent as a sub-sector in agriculture. This presents an opportunity for increased smallholder involvement.

CHAPTER 3: THEORETICAL FRAMEWORK

A large body of research exists on different aspects of cropping systems and land use. Over the past 50 years, explanations of changing cropping patterns have emerged from varying theories. Early studies largely examine land productivity and its association with various dimensions of agricultural transformation on a macro scale. Later, much literature built on the theories of the individual using the agricultural household model. The following section provides a review of literature on crop diversification and its determinants, ending with literature of the agricultural household model. The literature cited around crop diversification is meant to provide an overview of not only its broad economic implications, but also how farmers make decisions on which crops to cultivate based on a set of factors supported by literature.

3.1 Crop Diversification

The degree of crop diversification can range from total specialization, to high levels of diversity in which there are a greater variety of crops under cultivation (Turner 2014). Regionally, crop diversification is based on its changing social, economic, technological, geographical and institutional structure (Kumar 2004). From a smallholder's perspective, diversification decisions are made jointly bearing production and consumption decisions in mind, while household, farm and regional characteristics are the main factors that affect their land allocation decisions. Inderjit Singh (1985) proposes the canonical agricultural household model that elucidates land allocation decisions. Much research on crop diversification emerged following the Green Revolution that took place in Asia, such as Minot[2] (2006) and Ghosh[3] (2014). More recently, studies that focus on these patterns in Africa are becoming prominent.

3.1.1. Crop Specialization

Monoculture is the complete form of specialization, typically of grain crops in many developing countries. Nevertheless, specialization can also refer to high levels of crop

[2] Minot, Nicholas, ed. *Income diversification and poverty in the Northern Uplands of Vietnam*. Vol. 145. Intl Food Policy Res Inst, 2006.

[3] Ghosh, Madhusudan, Debashis Sarkar, and Bidhan Chandra Roy, eds. *Diversification of Agriculture in Eastern India*. Springer, 2014.

concentration. Kurosaki (2003) explains that the patterns of crop specialization and diversification allow us to characterize the nature of that region's agricultural transformation. Recent literature has identified a U-shaped relationship between a nation's level of crop diversity and the extent of the market (Shilpi and Emran 2012). Lesser developed markets often have higher levels of crop specialization, and as its markets develop, levels of crop diversity increase before reaching economies of scale, returning to specialization. Specialization occurring in economies of scale can be seen in the corn belts of the United States, for example (Haplin 2000).

In lesser developed countries, specialization is often associated with low levels of commercialization and rural market development (Haplin 2000; Kurosaki 2003; Minot 2006). In Uganda, for example, rural areas exhibit many of the characteristics of a lesser developed country, such as low density and quality of infrastructure, unsophisticated markets, and low levels of technology. In such instances, where markets may be difficult to access due to high transaction costs, production decisions are much related to food access. Therefore, the choice and extent for a household to diversify its crop portfolio will depend on its level of commercialization, whether it be subsistence, semi-commercial, or a fully commercial system (Ahmadzai 2017).

Kim (1981) provides several detailed motives as to why a producer might choose to specialize. The first deals with the availability of factor resources, which can range from land typology, soil type, climate, to human resources such as crop specific knowledge and expertise (Kim et al. 1981). Cultivating crops that are unfamiliar to farmers presents a risk, so areas that have historical trends of monoculture or little diversity are difficult patterns to break if proper expertise and working knowledge is not available (Minot 2006). Furthermore, many developing countries lack diversified markets which hinders the ability to diversify. In such instances, those countries are also frequently subsidizing a narrow range of commodities which will incentivize further production of those crops (Haplin 2000). Generally, constrained market access will hinder the range of products produced by limiting exposure to information and access to inputs, increasing the prospect of specialization. Many of the same dynamics which influence specialization are inversely related to diversification.

3.1.2. Crop Diversification and Determinants

In developing countries, agricultural diversification traditionally refers to a subsistence form of farming where farmers are cultivating varieties of crops on a plot of land and engaging in several enterprises on their farm portfolios (Vyas 1996). Common definitions hold that there is a shift from less profitable to more profitable crops (Vyas 1996). Higher valued crops usually include horticulture, spices, oilseeds and cash crops. The emergence of crop diversification is an indication that two things are happening 1) changing business activities where farmers are responding to changing opportunities such as new production technologies and price signals in the market (Abro 2012) and 2) more efficient allocation of resources (Mukherjee 2010). This results in greater economic returns, bringing about land productivity increases with greater inclusion of high-value crops (Rao 2006).

The process of agricultural diversification resembles similar patterns of diversification in non-agricultural sectors. In theory, the utilization of surplus capacity will lead to a related firm's diversification bound by the absence of market failure (Wernefelt and Chaterjee, 1991) (Haplin 2000). The initial stage of diversification in agriculture can be viewed as a shift away from monoculture (Haplin 2000). The resultant stage can be classified as when a farmer has more than one crop enterprise and he can sell or produce as he chooses throughout the year, known as the mixed farming stage (Metcalf, 1969; Shucksmith et al. 1989). Lastly, the process of diversification transitions into activities beyond primary agriculture (Newby 1988). These activities often include on-farm processing and the creation of non-agricultural products and services, as well as venturing into off-farm employment – a key step in agricultural transformation (Evans and Ilbery, 1993; Reardon and Timmer 2014).

Changes in aggregate land productivity are associated with the efficiency of resource allocation (Kurosaki 2003). Land use is a substantial part of resource allocation decisions, which includes what crops to plant and what proportion. In theory, a nation will use its resources optimally and will therefore allocate its land to maximize output. From a policy point of view, its promotion is meant to increase the country's self-sufficiency and provide a broader export base (Abro 2012). At the farm-level, it is becoming widely recognized as an avenue to increase and stabilize farm incomes (Mofya-Mukuka et al. 2016). Despite there being many individual determinants that are driving or hindering a farm's level of diversity, they can be broadly summarized within the contexts of risk, infrastructure and market development (Dutta 2011).

Risk

Risk and uncertainty are inherent features in agriculture (Ali 2015). Income uncertainty can lead to substantial welfare costs for households. Small-scale farmers, especially in developing countries can be unfavorably affected by drought or price fluctuations and diversification can be used as a strategy to hedge against such risks and uncertainty (Minot 2006). Crop portfolio diversification is analogous to the diversification of marketable stocks or bonds and these decisions are made to minimize risk and maximize long term gains (Moore and Snyder 1969). Small-scale farmers are believed to exhibit risk-averse behavior which is associated with the decision of which crops to plant and how much land to allocate to them (Fafchamps 1992). The primary factors that contribute to perceived farming risk are prices and yields, which are affected by a host of factors (Dercon 1996).

Mcguire (1980) conducted a study on production patterns across various states in the United States analyzing southern farmers who cultivated corn and cotton. His research aimed to rectify previous controversy among economists who theorized that southern farmers were in fact risk 'gamblers' rather than risk-averse. This initial claim was in response to an upsurge in the proportion of land devoted to cotton production away from maize because cotton was perceived as a riskier crop due to its market price volatility. His analysis sought to understand if farmers selected their crop portfolios in a risk-averse or risk-seeking manner, based on expected prices. A behavioral model that calculates farmer's subjective risk coefficients in relation to land allocation decisions was employed. Of his sample of 45 farmers over eight years, all of them displayed positive coefficients indicating that farmer's attitudes toward risk were risk-averse and homogenous despite heterogeneous populations.

Empirical approaches have been taken to quantify the exposure of downside risk under the production of various crops. Di Falco and Chavas (1996) used a stochastic production function to assess welfare effects from biodiversity on production risk. Since farmers are considered to be risk averse, he hypothesizes that risk exposure will make farmers worse off, which implies a positive cost of risk. Avoiding risk exposure indicates that there will be an incentive to grow a variety of crop cultivars that will increase the skewness of the distribution of returns. His findings indicate that biodiversity is strongly related to the skewness of production. The results concluded that land fertility and crop biodiversity were substitutes – agreeing with theory. This implies that greater number of crop varieties reduce the exposure to downside risk in areas where crop failure is more likely.

Infrastructure

Inadequate transport and communications infrastructure in remote areas has been obstacle to improving productivity, income, and food security in rural Africa (Turner 2014). Farmers have been impeded by these constraints when trying to purchase inputs or sell their surplus (Barrett 2017). In many lesser developed countries, markets for high-valued agricultural products are concentrated in urban and semi-urban areas (Rao 2006). Transport arrangements from rural to urban areas are often scant which results in increased transaction costs for producers, discouraging market participation and thus, diversification toward higher-value products. Access to markets, transportation facilities and post-harvest infrastructure have been cited as critical aspects to the growth of high-value products and crop diversification, although infrastructure has been considered to include many other aspects such as roads, electricity, telecommunications, transport, and irrigation facilities (Rao 2006).

Numerous studies have examined how different infrastructural facilities play a role in agricultural household decisions. Rao (2006) studied the impact of roads and urbanization on the production of high-value commodities in India from 1980 to 1988. Road and population density are his key variables of interest in relationship to regions of high-intensity production of high-valued commodities. His findings show that greater land concentrations of high-valued commodities were in regions with greater population pressure, higher road density, and a larger urban population. Concentrations of high-valued commodities decrease with distance to urban centers. High value agriculture comprised 4 percent of the value of agricultural output in urban areas while only 32 percent in far urban areas. He argues this occurrence suggests urbanization is an important factor in the growth of high-value production from the demand side, while greater supplies of labor and infrastructure facilitate the process.

a

Markets

Abounding literature highlights the negative impacts of market failure and how agricultural productivity cannot thrive in its presence. From a micro or macro perspective, market development has been widely cited as a key force in driving structural transformation, as well (Timmer 1988; Barrett 2017). Market development facilitates crop diversity by building working capacity, connecting farmers with information and inputs.

Early attempts to properly describe peasant farmer's behavior were confounding and many researchers believed the utility maximization approach was an ineffective technique proposed by formal economists. Governments were frustrated by policies that were rendered ineffective which aimed to promote technology adoption and price stability of crops because they saw no change in farmer's behavior. De Janvry (1991) offered a seminal explanation of market failure from the perspective of the agricultural farmer to remedy the debate. De Janvry described how previous theories did not adequately take into consideration all of the peasant farmer's choice variables in maximizing utility. In other words, the incentives thought to be in place to elicit a reaction from farmers were constrained by unseen information, such as high transaction costs when selling their produce.

Immink and Alarcon (1993) examined the complete substitution between food and cash crops to explore changing patterns in farmer's crop mixes during a period of commercialization of small-scale farmers in Guatemala. With nationally representative cross-sectional data, they categorized households into four groups of different crop mixtures and estimated the probability of a household choosing one of the crop portfolios. Their key finding was that the lack of access to credit markets was a key constraint to technology adoption.

Various authors support the findings that access to inputs are essential to agricultural productivity. Chavas (2001) conducted a study using nonparametric methods estimating a variety of productivity indices. The analysis studies twelve developing countries between 1960 and 1994 to analyze the contribution of each type of input to aggregate production. The time-series results disaggregated the factors associated with agricultural output. Technology remained relatively the same over this time period and the greatest contributor to output was inputs such as fertilizer and pesticides.

Kibaara et al. (2009) examined the drivers of agricultural productivity using household panel data in Kenya based on the availability of input markets. The study analyzed output changes in maize, tea, coffee, sugarcane, cabbages, Irish potatoes and dairy. A Cobb-Douglas production function was used to measure productivity changes. Increased productivity in maize was the result of greater numbers of small holder farmers using fertilizer, improved seed varieties, and the availability of fertilizer retail outlets. Increased dairy output was described as the largest response to increased investment, indicating access to financial services as the key driver.

3.2 Agricultural household models

The theory of the agricultural household model has been the building blocks for many researcher's framework in agricultural economics. Originally created as a method for price policy analysis, it has been applied to a wide range of topics from technology adoption, production functions, deforestation, to biodiversity. Since its origins, dating back to Chayanov (1925), nuanced versions have come to incorporate various features seen in lesser developed countries' rural economies, such as imperfect or missing markets for inputs and outputs, labor and the existence of transaction costs, among others (Taylor et al. 2002). Currently, the framework of Singh (1985; 1986) has emerged as some of the most recognized and replicated. The following sheds light on the origins, evolution and theoretical framework of agricultural household models and how it is relevant to this study.

Chayanov (1925) created one of the first agricultural household models of resource allocation based in rural Russia. It sought to explain the role of the rural peasant economy as the country transitioned from feudalism to socialism. Agricultural productivity was analyzed, but limited to the nuclear household, thus making own demographic characteristics explain to a large extent its outcomes (Hammel 2005). Its formulation, therefore only included a product market, but no labor market. Its main criticisms and limitations have been his exclusion of factors beyond agricultural, such as labor and capital flows (Shanin 1986).

Mellor (1963) and Sen (1966) among several others,[4] later formulated their own agricultural household models that built on Chayonov's earlier principles. Their work added by exploring output outcomes considering variable inputs and the demand for leisure. Through the income

[4] Tanaka (1951), Nakajima (1957; 1969)

effect, households may respond negatively to output prices if they have a large demand for leisure (Singh et al. 1986). Nakajima (1969) posited that labor supply and output price had a substitutable effect. Together, the work of Nakajima and Sen showed that the marginal utilities of income and leisure were relatively constant (Singh et al. 1986).

An updated portrayal of factor markets, specifically for hired waged-labor was provided by Barnum and Squire (1980) to further explore the relationship of output and labor demand and supply. The results of their models showed that labor demand will respond positively to output price in the event that it is not an inferior input, once they extended crop production beyond staples to include cash crops (Singh 1986). Jorgenson and Lau (1969) followed this by developing a separable subsistence model that allowed for household labor to be marketed and household production is only partly for own consumption (Singh 1986).

Singh built his own model that incorporates many of the foundations provided before him. Singh's form was developed as a tool for price policy analysis in rural Japan (Kuroda and Yotopoulos, 1978) tailored to the circumstances of developing countries to reflect missing or incomplete markets for outputs and inputs (Taylor et al., 2002). An increase in the price of a staple crop did not elicit the expected response policy makers thought it would have on farmer's marketed surplus. In efforts to comprehend this behavior, a model was proposed which simultaneously considered both production and consumption when making household decisions.

Prior economic theory dealt with production and consumption decisions separately, but the reality is that in developing countries, agricultural households often integrate their consumption and production decisions (Singh, Ahn and Squire 1981). Such decisions are integrated by the necessity to select inputs for household crop production, while consumption decisions are made based on the allocation of farm income and production to purchase goods and services. A household's profits are implicitly determined by household production minus consumption of its own goods, and purchased goods. Singh's standard model consists of a utility function defined by consumption for each household member with a budget constraint that includes production on owned assets. Household utility is a function of the consumption of goods and leisure time. Maximizing utility is with respect to consumption, leisure, hired labor, land, household labor, rented land and used land on the farm. This is bound by the budget constraint which includes cash expenditures, hired labor, and own rented land which cannot be greater than its own cash revenue (Singh 1986).

Various studies have applied a similar framework to different areas within agricultural and resource economics. This study extends the model to question which crops to produce and how much land should be allocated to each. Econometrically, estimable versions of these models have been applied to crop choice, land allocation and diversity outcomes (Benin 2003). The following will provide greater insight to the empirical structure of the agricultural household model. Below follows Singh's (1986) basic model framework, then provides the multiple crop model to demonstrate crop choice and land allocation decisions. This will serve as the foundational theory as to how households make diversification decisions toward HVA.

3.2.1 Basic Model

The utility function can be illustrated as, $\max_{A_a, M_m, X_L} U(A_a, M_m, X_L)$ where the objective is to maximize expected utility from household-produced goods, purchased goods, and leisure while facing several constraints. In the utility function, A_a is production of an agricultural staple, M_m is a good that is purchased in the market, and X_L represents leisure time in hours. Under these conditions, the household faces the following constraints of; cash income, time, and production technology. First, the cash income constraint can be defined as:

$$p_m M_m = p_a(Q_a - A_a) - w(L - F) - z_v V + E \tag{1}$$

Intuitively, this constraint implies that a household can purchase in the market only with the earnings from its own surplus production. In the budget constraint equation, p_m represents market purchased goods while p_a represents the price of the household producing its own agricultural products; Q stands for the quantity of agricultural products produced by the household such that $Q - A_a$ is the household's marketed surplus. The wage rate is denoted as w in the market and L and F are total labor inputs and family labor inputs, respectfully. When $L - F$ is positive it indicates the household hired labor and when negative, the household has off-farm labor supply. Variable inputs such as, fertilizer or seed are represented as V, while z_v is its market price. Household income, E is earned not from labor or from the farm.

Secondly, the time constraint can be illustrated as:

$$X_L + F = T \tag{2}$$

Here, leisure time plus on farm or off-farm employment cannot exceed the total available time to the household, T. Lastly, the production constraint that is thought to be based on the household's production technologies illustrates the relationship between inputs and output as:

$$Q_a = Q(L, V, Z, K) \qquad (3)$$

The new variables presented in this constraint include Z, the household's fixed quantity of land and K represents the household's fixed level of capital. Ultimately, this constraint describes how production is a function of labor inputs, variable inputs, and fixed quantities of land and capital.

The constraints can be then substituted into a single equation that will form part of the final utility equation. To collapse all of the constraints into one equation by substituting where necessary, we have:

$$p_m M_m + p_a A_a + wX_L = wT + \pi + E \qquad (4)$$

The left-hand side of constraints equation can be seen as total household expenditure on market-purchased goods, the household's expenditure of its own output, and the purchase of its own time in the form of leisure. The right-hand side of the equation (x) is Becker's development of the full-income concept which denotes the value of the stock of time, wT owned by the household, plus farm profit, π, plus off-farm income, E, is equal to total household profits. With this information, the equation for farm profits can be derived as:

$$\pi = p_a Q_a(L, V, Z, K) - wL - z_v V \qquad (5)$$

The current model assumes that the household produces one crop, a. To analyze crop diversification decisions based on the agricultural household model, we must further develop the model to include multiple crops.

3.2.2 Multiple Crop Model

To understand how a household makes decisions on how to allocate its land between multiple crop choices, I borrow the conceptual model from Turner (2014) and Benin et al. (2004) that has been extended from Singh (1986). We assume the farm-household produces a vector of outputs, Q from a vector of inputs, X. Building on the equations from the single crop model, the farmer's production function for each crop, j becomes:

$$Q_j = f\left(\boldsymbol{X}_{jk}, \alpha_j \middle| A, \Omega\right) \quad (6)$$

A is a fixed amount of land for the household, as before. Household utility is derived from different consumption bundles, and its levels depend on the preferences within the household. We therefore assume that preferences are determined by characteristics of the household such as, age, education and wealth, which will be represented as Ω; and α_j represents the share of land, A allocated to crop, j. The profit equation can then be generated by the sum of outputs for each crop minus the inputs costs which can be seen as:

$$\pi = \sum_{j=1}^{j} p_j Q_j - \sum_{k=1}^{j} w_k X_{jk} \quad (7)$$

Here, p_j and w_k represent vectors of output and input prices, respectively. The equation is arranged to maximize the household's expected utility:

$$EU = (\pi(Q, X, p, w|A, \Omega) \quad (8)$$

And optimal level of inputs are then found by applying the first-order conditions with respect to X, such that:

$$X_{jk}^{*} = X_{jk}^{*}\left(p_j, w_k, U \middle| A, \Omega\right) \quad (9)$$

Finally, we can then solve for the optimal output level of each crop j which is dependent on X_{jk}^{*} as:

$$Q_j^{*} = f\left(X_{j1}^{*} \dots X_{jk}^{*}\right)|A, \Omega \quad (10)$$

Transaction costs, rather than realized prices are represented in household characteristics like physical access to markets, therefore are better represented in a new vector, ϑ for market characteristics. However, Turner (2014) contends that regional market prices are an adequate substitute because they observe prices at large, which will capture exogenous price variation that is likely unaffected by the individual household. Under Turner's modification to Benin, we can account for district-level market prices as p and transaction costs in the form of physical market access that falls under market characteristics. The optimal crop mix expressed as the optimal level of land α_j, allocated to each crop j so that, $\sum_{j}^{J} \alpha_j = 1, j =$

$1,2, \ldots J$, is a function of farm size, market prices, market and household characteristics such that:

$$\alpha_j^* = f(A, P, \Omega, \vartheta) \quad (11)$$

Broadly defined, these are the hypothesized factors that affect household crop diversity. The applied econometric approach will attempt to identify the relevant variables that have been mentioned in the agricultural household model holding that households behave to maximize expected profits through agricultural production, and therefore having the optimal crop mix.

3.3 Previous Application of Crop Diversification Models

Application of fixed effects estimations have previously been used to examine a wide range of crop diversification outcomes. Many fixed effects approaches when applied to crop diversity analyze nutritional or crop yields and their relationship with crop diversity. More recently, household models that explore the determinants of household crop diversification have been undertaken. Kurosaki (2003) provides an analysis of the dynamics of crop diversification at the district level to understand cropping patterns of subsistence farmers in the Western Punjab with data from 1903-1992. This study utilized the Herfindahl-Hirschman index to characterize temporal and spatial crop shifts. Results concluded that changes in district-level crop diversity reflected that regions, comparative advantage is based on its geographic features and level of market development.

A study conducted in India by Birthal (2007) explores the hypothesis that diversification toward high-value crops, such as fruits and vegetables can reduce poverty through smallholder participation with fixed effects. Population density, urbanization, and per capita incomes are the main controls from the demand side. Water availability, production technology resource endowment, and infrastructure features such as roads and markets are his hypothesized supply side factors that facilitate diversification (Birthal 2007). He states that diversification toward fruits and vegetables usually requires greater levels of capital, relative to other crops. The key variables of interest are access to credit and capital related factors since many higher valued products may be capital intensive. These variables proved to be significant in crop diversity shifts toward high value products. Results also suggested that the uptake of riskier crops was considered as deterrents to smallholder participation, while crops such as fruits that required less prior working knowledge were more frequently adopted.

Abro (2012) used a generalized least squares model with fixed effects to examine the impact of different forces on crop diversification in Pakistan using panel data from 1980-2011. Tube wells for irrigation and length of roads were both significant variables which contributed positively toward diversification. Tube wells provide water for irrigation. Thus, proving that the availability of water is one of the determinants of crop diversity through high paying off-season crops such as vegetables in Pakistan (Chand 1995).

In Zambia, a study was conducted by Mofya-Mukuka et al. (2016) to analyze the factors influencing household crop diversity. The dependent variable used was the Simpson Index of Diversity to express crop diversity with a fractional response probit and correlated random effects for the model estimation as prescribed by Wooldridge (2010). The motive of the study was to better understand why diversification beyond staples in Zambia is so little. The key outcome of interest was to explore how government subsidies impact household crop diversity. Results indicate that, since the government provides input and marketing subsidies for maize, it negatively impacts smallholder crop diversification. Furthermore, extension service contact, productive assets, hours to nearest urban center, annual average rainfall and landholding size were all significant variables with positive relationships to household crop diversity.

3.3.1 Research Application

The triple-hurdle model is a modern technique that was developed and first implemented by Bill Burke in 2009. It has been developed to test its validity surrounding market participation questions against commonly used approaches, such as ordered tobit models and double-hurdle models. Its framework is built on previous double-hurdle models that consist of two-stage decisions and outcomes. Traditional double-hurdle approaches to market participation in agricultural economics are misspecified unless all of the population in the sample are producers of the good in question, as with staple commodities. When studying a less commonly produced good, such as dairy of HVA, this method is less appropriate. This limitation can be overcome by including a third hurdle; to model the initial decision to produce. This technique improves inference by addressing the fact that the decision to produce or cultivate the good may or may not be driven by a different structural process than participation in marketing (Burke et al. 2015). In real application, policies and other incentives that induce market participation of HVA may also induce non-producers to being producing, leading to significantly different estimates of an overall effect. This could provide useful policy information.

The following will provide the intuition and rationale of the double-hurdle, a review of its application and the framework laid out by Burke et al. (2015) for a triple-hurdle estimation that will be used in this study.

3.3.2 Review of Double-Hurdle Applications and Triple Hurdle Background

A dilemma in econometric modelling can arise when an outcome of interest depends on a prior condition being met that less frequently occurs within the sample population. Models of agricultural market participation are prime examples of this problem. If a researcher chooses to examine how smallholder farmers participate in markets and their quantity of maize sold, the second outcome can only be realized if the household is a market participant. Thus, in the event that a household does not participate, the value of sales will be zero. This requires utilizing an approach where the parameters of the model can be estimated non-linearly, making traditional ordinary least squares an inappropriate method for this research question. Nuanced approaches to account for statistical challenges such as these use corner solution models. The rationale for the double-hurdle method is to simultaneously analyze the decision not to participate in the market which could provide valuable information, rather than ignore those observations. Double-hurdle models have been developed to examine cases where an event may or may not occur, though if it does, it takes on a continuous value (Burke et al. 2015; Mather and Jayne 2011).

Foundations for double-hurdle models are built on Tobin's (1958) tobit model. The tobit model, was designed to estimate linear relationships between variables when there is censoring of the dependent variable (Tobit 1958). Cragg (1971) developed a model as an "alternative" to Tobin's that has become widely used for its flexibility in comparison with Tobin's approach. Cragg's model differs by breaking the tobit model into different components where only the first stage parameters in the model determine the probability of a limit observation, followed by a separate set of parameters to determine the density of non-limit observations (Lin and Schmidt 2004). The rationale for a double-hurdle application is to observe an outcome conditional on that outcome being realized.

Applications of double-hurdle models have become popular in agricultural economics, specifically for studies dealing with market participation and a following continuous outcome. Goetz (1992) was the first to borrow this framework in an application to market participation and output quantities. In his two-tier approach, he first uses a probit to gauge the probability that a household participates in the market via sales or purchases. The second tier explores the quantity of how much is sold or bought in the market.

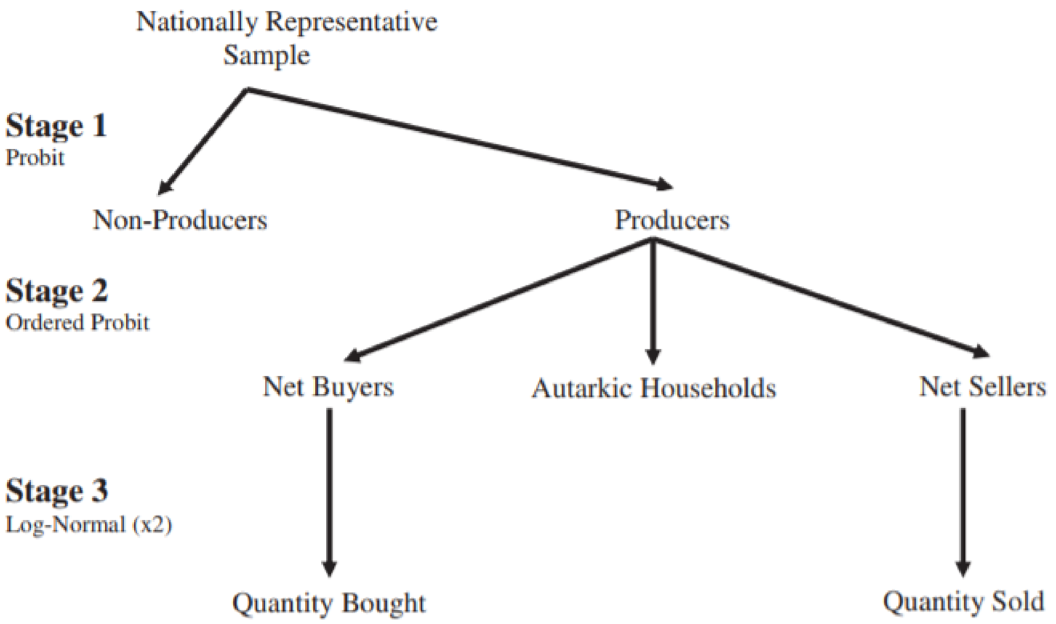
Barrett (2005; 2006) has employed double hurdle models on a variety of occasions. Bellemare and Barrett (2006) evolve Goetz's model to include an ordered probit in the first stage to measure the probability of a household being net buyer, net seller, or autarkic. The second outcomes uses a truncated normal regression to measure the quantities bought and sold.

Turner (2014) uses correlated random effects with Cragg's double-hurdle to estimate pigeon pea cultivation and its area allocated with Mozambican panel data. She includes correlated random effect techniques because she argues unobserved time-constant factors influence the decision to cultivate pigeon peas. Thus, her first stage is the decision to cultivate pigeon pea, and conditional on this outcome, how much area is then allocated to pigeon pea as a share of total area. The key focus was to understand how infrastructure variables, particularly radio ownership and mobile networks impacts on pigeon pea cultivation. Households who own radios are believed to have greater access to information, in turn, their area allocated to pigeon peas may be more responsive to information on prices. Her results found that among these variables, radio ownership and pigeon pea price were significant in influencing the decision in how much land is allocated to pigeon peas, if the household is a pigeon pea producer.

More recently, Burke et al. (2015) extends the double-hurdle framework to include a third hurdle. As has been seen in double-hurdle models, participation decisions unfold in two steps; (1) an initial decision whether they participate and (2) what quantity to buy or sell. Such models have been formulated around goods that are commonly produced, such as staple crops. Therefore, this method is appropriate because typically all of the population in the sample produces the good. However, the analysis would then change if it were extended to include crops more seldom produced by smallholders, such as dairy, cash commodities, or horticulture. Burke argues that for inference applicable to the broader population, the decision to cultivate the crop in question should be the initial hurdle. Thus, a third hurdle would be added to the existing double-hurdle model.

Burke applies this method to smallholder farmers in Kenya and their decisions on market participation in the dairy sector. His model's decision process becomes 1) Does the household produce dairy 2) is the producing household a net buyer, autarkic, or a net seller, 3) what are the quantities bought and sold amongst market participants? Stage one represents a binary decision of yes or no, and a probit model is employed. Stage two classifies smallholders into three categories and makes use of an ordered probit. Lastly, two log-normal regressions are used to analyze net volumes bought or sold (Burke et al. 2015). A graphic illustration of the decision process can be seen in figure 4.1 as:

Figure 3.1: Triple-Hurdle Modeling Framework



Source: Burke, 2015

Burke's aim was to analyze the factors associated with smallholder farmer's participation in dairy markets since it is considered to have great potential to enhance incomes. The findings from his research show that a triple hurdle model can be superior to previous methods such as double-hurdle or ordered tobit models. Burke's results indicate that improved technologies play a large role in the participation of dairy production and marketing. Furthermore, access to land, the value of household productive assets, infrastructure and improved technologies were statistically significant factors related to the probability of being a producer and being a net seller. Infrastructure examined distance from electricity, which is statistically significant and the probability of being a seller is inversely related to its distance. Considering that dairy production can have significant initial investment, access to credit proved to be an important factor to dairy market participation. One of the highlights of Burke's findings show that where dairy cooperatives are present households are 9-10% more likely to be net sellers, unconditional on whether or not households are producers.

CHAPTER 4: EMPIRICAL FRAMEWORK

The objective of the study is to identify the factors that influence the cultivation of high-value agricultural products in Uganda, household market participation outcomes, and net sales (for net sellers) or net purchases (for net buyers) in the market, conditional on being HVA producers. To address this objective, the triple-hurdle model is utilized. The empirical specifications and methods of estimation are discussed in this chapter.

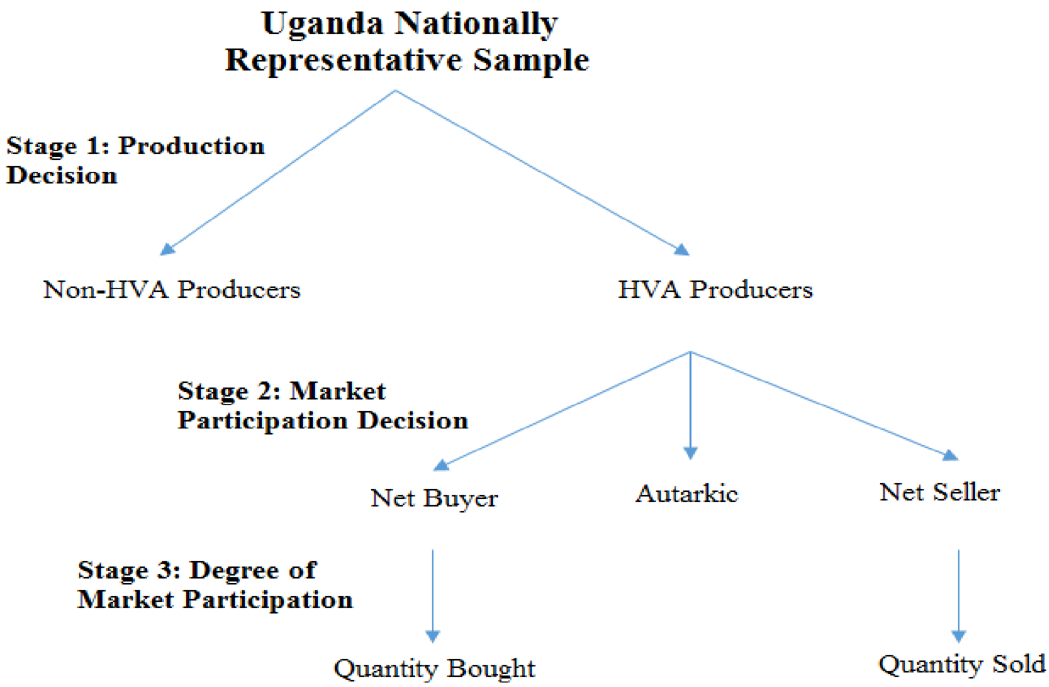
4.1 Methodology: Triple-Hurdle Model

The empirical model used to understand the factors that underpin a household's decision to produce and participate in markets of high-value products, relies on the economic justification of the market participation models discussed in Chapter 3. Following Burke et al. (2015), a triple-hurdle framework models the three stages of decision-making that Ugandan HVA farmers face, these include;

1. Stage 1: The decision to produce high-value products (as defined in Chapter 2)
2. Stage 2: The decision to participate in the market as either a net buyer, net seller or neither (autarky).
3. Stage 3: The degree of market participation, i.e. the net volume bought or sold

Figure 4.2 below illustrates the household decision tree.

Figure 4.1: Decision Pathways: Triple-hurdle Modeling Framework



To identify the key factors influencing the decision to cultivate HVA and household market participation decisions that will be used in the triple-hurdle estimations, this study follows the approach of Mofya-Ukuka et al. (2016) and Burke et al. (2015). The factors determining the decision to cultivate HVA and participate in the market are hypothesized to be a function of demographic, farm, and regional characteristics. These can be seen as;

Demographic characteristics include gender, age and level of education of the household head, and full time adult equivalents. Female farmers generally face greater social barriers than men (Farnworth, Akamandisa, and Hichaambwa 2011). Age of household head is a proxy for experience which tends toward better farming practices, but may be less amenable to cultivate non-traditional crops. Full time adult equivalents represent a form of labor endowment and HVA can be capital intensive.

Farm-level characteristics include access to extension services, use of improved seed and hired labor, value of household productive assets, and household landholding size. Elevation of the plot, in meters above sea-level, access to extension services is a binary variable indicating yes or no to household extension service contact, along with whether the household used improved seed or hired labor. Value of household productive assets is a proxy for wealth which is widely believed to lead to different farming outcomes (Carter 2000; Mofya-Mukuka et al. 2016). Household landholdings is thought to help explain diversification decisions because households with less land may be less inclined to devote land to non-consumption crops.

Regional characteristics include annual average rainfall, distance to nearest market, population center, and nearest road, share of the district receiving credit, district prices for Ugandan HVA substitutes such as maize, beans, cassava, as well as the price of an HVA – Coffee. Infrastructure barriers such as distance to roads represent a form of transaction cost because they limit a farmers' access to distribute and sell their products. Long – term average rainfall is an agro-ecological indicator that influences the comparative advantage of producing staples.

The triple-hurdle model as proposed by Burke et al. (2015) uses full maximum likelihood to estimate all of the parameters in each stage of the model. This will be discussed more in the next section of this chapter. First, the justification of the selected methods and their conceptual derivations are laid out which will provide the foundations for the likelihood function to be estimated.

Stage 1. The Decision to Produce HVA

In stage 1, *whether the household produces HVA?* is either 1 (yes) or 2 (no). Unlike linear models that primarily examine continuous outcomes, the interest in binary response models lies in the response probability (Wooldridge 2013).

Linear probability models have been used to describe response probabilities for a sample population. However, dependent variable outcomes behave non-linearly due to the distribution of the marginal and are bound between the values of zero and one. In ordinary least squares (OLS) an issue arises because when using linear predicted probabilities, values can fall outside of this zero to one interval. Despite this problem, linear probability models have been seen as good approximation of response probabilities, although other models have been developed to that fit the non-linear nature of a sample population's response probability. Conventional approaches that solve this problem make use of probit and logit models to fit a non-linear function to the data.

Probit and logit models transform the outcome of response probabilities by indexing the explanatory variables into the cumulative density function over the interval zero to one. Wooldridge (2013) refers to this as the index model which can be seen as;

$$P(y = 1|\boldsymbol{X}) = \Phi(\boldsymbol{X\beta}) \equiv p(\boldsymbol{X}) \quad (12)$$

Where φ is the cumulative distribution function which takes a specific form depending on the underlying economic model, which maps $\boldsymbol{X\beta} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n$ over the response probability. This can also be represented as;

$$P(y = 1|\boldsymbol{X}) = y = \Phi(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n) \quad (13)$$

Equations (12) and (13) can be interpreted as the probability of an event occurring conditional on the exogenous explanatory variables (***X***) according to a vector of the parameters to be estimated ($\boldsymbol{\beta}$). By making use of the Bernoulli formula, that predicts binary outcomes, where in the event that a response does occur, is equal to the cumulative density function (CDF) denoted as Φ, which is the covariates distribution, ***X***, when *y*=1. The index model uses a latent variable model to derive the CDF from the underlying model, which takes the form;

$$y = \boldsymbol{X\beta} + e, \qquad y = 1 \; if \; y > 0 \; otherwise, y = 0 \quad (14)$$

Where the event occurs, $y = 1$ if $[y > 0]$, *e* is a continuously distributed variable independent of ***X*** symmetric around zero and Φ is the CDF of *e* thus describing how in equation (12) that $\Phi(\boldsymbol{X\beta}) \equiv p(\boldsymbol{X})$ (Wooldridge 2013).

Both logit and probit models make use of a CDF, but use different functional forms. The logit assumes the CDF of the logistic distribution and the probit assumes the standard normal cumulative density function. The probit's interpretation involves marginal effects associated with changing probabilities of the response outcome given a unit change in an explanatory variable, ceteris paribus. Despite their differences, they usually yield similar results and their preference is often discipline specific. In economics, probit models tend to be more intuitive due to their marginal effect interpretation.

The interpretation of the parameters in a standard probit regression should be interpreted based on its sign, while no specific inference can be made given the isolated effect of the parameter on the dependent variable. Coefficients with positive signs indicate that increasing values of a given variable's coefficient will have greater probabilities of *y*=1, while increasing values of variables with negative coefficients indicate decreasing probabilities of *y=1*. The marginal effects in a probit model offer the isolated change in the response probability given an incremental change in an individual explanatory variable, all else constant. Building on equation (13), to obtain the marginal effects from a probit regression, it requires taking the derivative of a CDF with respect to a given explanatory variable. This will yield the marginal impact of on the response probability by changing an explanatory while setting other explanatory variables to specified value. The marginal effect can be seen as;

$$\frac{\partial y}{\partial x_i} = \beta_i \Phi(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n) \tag{15}$$

Probit models parameters are estimated via maximum likelihood. The following first estimates the distribution of y which will be used in the log-likelihood function for each observation i, however, the econometric estimation of the log-likelihood function will be described in the next section. The following shows the distribution of y_i given $\boldsymbol{X_i}$ which can be seen as;

$$f(y|\boldsymbol{X_i}, \boldsymbol{\beta}) = [\Phi(\boldsymbol{X_i}\boldsymbol{\beta})]^y [1 - \Phi(\boldsymbol{X_i}\boldsymbol{\beta})]^{\mathbf{1}-y}, \quad y = 0, 1$$

In the context of the triple-hurdle, the structure of the first stage decision, whether or not to produce HVA can be represented with a probit model. For simplicity, the conceptual framework will build on the following notation;

$$c_{1i} = 1[y_1 > 0] \tag{16}$$

$$c_{1i} = 0[y_1 = 0] \tag{17}$$

In the first stage the conceptual framework for the standard probit can then be seen as;

$$Pr(Cultivate\ HVA) = Pr(c_{1i} = 1|\boldsymbol{X_{1i}}) = \Phi(\boldsymbol{X}_{1i}\boldsymbol{\beta}) \tag{18}$$

$$Pr(Cultivate\ HVA) = Pr(c_{1i} = 0|\boldsymbol{X_{1i}}) = 1 - \Phi(\boldsymbol{X}_{1i}\boldsymbol{\beta}) \tag{19}$$

$$f(c_{1i}|\boldsymbol{X_{1i}}) = (1 - \Phi(\boldsymbol{X_{1i}}\,\boldsymbol{\beta})^{1[c_{1i}=0]}(\Phi(\boldsymbol{X_{1i}}\,\boldsymbol{\beta})^{1[c_{1i}=1]} \tag{20}$$

Where y_1 represents the household's production levels if the household produces HVA. The *1* in c_{1i} represents the stage one decision for any given household, *i*, to cultivate HVA given $\boldsymbol{X}_{it}$, the hypothesized explanatory factors that influence this decision, and $\boldsymbol{\beta}$ represents a vector of the coefficients to be estimated in stage one. Equation (18) represents the probability that the household does produce, whereas (19) represents the probability that it does not. Equation (20) demonstrates the Bernoulli distribution showing equations (18) and (19) in the same equation. Conditional on households passing the first stage hurdle, they reach the second stage, so that all of the population that proceeds are HVA producers.

Stage 2. Market Participation Decision

As the decision tree indicates, in the second stage, households are separated between net buyers, autarkic, and net sellers, all of whom are HVA producers. Conditional on the household being a HVA producer, they reach the second stage decision; the decision to participate in the market and to what extent. There are three outcomes this study explores in stage two which are the probability of the following; 1) being a net buyer 2) autarkic (does not participate) or, 3) be a net seller in the market. Like the stage one decision, a method that measures the probability of these outcomes occurring, based on the hypothesized factors that influence this decision is an appropriate method to address the research question. In stage two, an ordered probit is the elected method that predicts the probability of a household falling within one of the three specified market participation categories. Much of the same conceptual framework applies to the ordered probit as in the standard probit, although to include an additional outcome. Consider the latent variable model;

$$y^* = \boldsymbol{X\beta_2} + e \tag{21}$$

The observable criteria for the outcome values that y^* can take, *m* are defined as;

$$y^* = m \text{ if } \alpha_{m-1} \leq y^* \leq \alpha_m \text{ for } m = 1, \dots, M \tag{22}$$

$$\text{Where } \alpha_0 < \alpha_1 < \alpha_2 < \dots < \alpha_M \text{ and } \alpha_0 = -\infty \text{ and } \alpha_M = \infty \tag{23}$$

The alphas, α denote the thresholds that define the cutoff points for the ordinal values of the dependent variable. Therefore, given the three outcomes, the predicted probabilities of each ordinal outcome is;

$$Pr(y = 0) = p(y^* \leq \alpha_0) = \Phi(\alpha_0 \text{-} \boldsymbol{X\beta_2}) \tag{24}$$

$$Pr(y = 1) = p(\alpha_0 \leq y^* \leq \alpha_1) = \Phi(\alpha_1 \text{-} \boldsymbol{X\beta_2}) \text{ - } \Phi(\alpha_0 \text{-} \boldsymbol{X\beta_2}) \tag{25}$$

$$Pr(y = 2) = p(\alpha_1 \leq y^*) = 1 - \Phi(\alpha_1 - \boldsymbol{X\beta_2}) \qquad (26)$$

The full distribution of y^{θ} in the ordered probit can then be seen as;

$$f(y^*|\boldsymbol{X}) = [\Phi(\alpha_0 - \boldsymbol{X\beta_2})]^{1[y=0]} * [\ \Phi(\alpha_1 - \boldsymbol{X\beta_2}) - \Phi(\alpha_0 - \boldsymbol{X\beta_2})]^{1[y=1]} * [\ 1 - \Phi(\alpha_1 - \boldsymbol{X\beta_2})]^{1[y=2]} \qquad (27)$$

Like in the standard probit, the parameters from an ordered probit regression should be limited to the sign of the parameters. The interpretation from the ordered probit regression differ from the probit, because they include a third outcome. Given that net buyers are equal to zero, autarkic are equal to one, and net sellers are equal to two, increasing values of the variables with positive coefficients indicate that the observations are more likely to be autarkic than net buyers, and more likely to be a net seller than autarkic (Burke et al. 2015). The marginal effects of the individual parameters can also be calculated for the ordered probit as in the standard probit (Equation 15), however, they are derived with respect to a specific outcome.

Applying this to triple hurdle framework, the notation proceeds with p_{2i} which will represent the stage two outcomes and y_2 indicate the quantity of market purchases. The following will denote the three outcomes of market participation;

$$p_{2i} = 0[y_1 - y_2 < 0] \qquad (28)$$
$$p_{2i} = 1[y_1 - y_2 = 0] \qquad (29)$$
$$p_{2i} = 2[y_1 - y_2 > 0] \qquad (30)$$

Equation (21) represents net buyers because the quantity purchased in the market for HVA producers, y_2 is greater than the quantity sold for HVA producers, y_1, therefore p_{2i} takes on the value of zero; equation (29) indicates the household is autarkic and does not participate and p_{2i} is equal to one; while equation (30) shows net sellers who sell more than they purchase and p_{2i} takes on the value of two. As mentioned by Burke et al. (2015), for estimation purposes for the ordered probit, it is necessary to have net buyers and net sellers on opposite sides of autarky. In stage two, we can define the latent variable as;

$$p_{2i}^* = \boldsymbol{X_2\beta_2} + e \qquad e|x_2 \sim normal \qquad (31)$$

Where $\boldsymbol{X_2}$ represents a vector of the explanatory variables determining the stage two outcome for market participation. According to Burke et al. (2015) the specifications in equations (28)-(30) will define the outcome of the latent variable within the specified thresholds denoted as α such that;

$$p_{2i} = 0 \quad if\ p^*_{2i} < \alpha_0 \tag{32}$$

$$p_{2i} = 1 \quad if\ \alpha_0 < p^*_{2i} < \alpha_1 \tag{33}$$

$$p_{2i} = 2 \quad if\ \alpha_1 < p^*_{2i} \tag{34}$$

Now that the outcomes are specified, notation can be derived that shows the probability of a particular market participation outcome;

$$pr(p_{2i} = 0|\boldsymbol{X_2}, \alpha, \boldsymbol{\beta_2}) = pr(p^*_{2i} < \alpha_0|\boldsymbol{X_2}) = \Phi(\alpha_0 - \boldsymbol{X_2\beta_2}) \tag{35}$$

$$pr(p_{2i} = 1|\boldsymbol{X_2}, \alpha, \boldsymbol{\beta_2}) = pr(\alpha_0 < p^*_{2i} < \alpha_1|\boldsymbol{X_2}) = \Phi(\alpha_1 - \boldsymbol{X_2\beta_2})1 - \Phi(\alpha_0 - \boldsymbol{X_2\beta_2}) \tag{36}$$

$$pr(p_{2i} = 2|\boldsymbol{X_2}, \alpha, \boldsymbol{\beta_2}) = pr(\alpha_1 < p^*_{2i}|\boldsymbol{X_2}) = 1 - \Phi(\alpha_1 - \boldsymbol{X_2\beta_2}) \tag{37}$$

The full distribution for the stage two ordered probit in triple-hurdle notation can then be seen as;

$$f(p_{2i}|\boldsymbol{X_2}) = [\Phi(\alpha_0 - \boldsymbol{X_2\beta_2})]^{1[p_{1i}=0]}\,[\Phi(\alpha_1 - \boldsymbol{X_2\beta_2})1 - \Phi(\alpha_0 - \boldsymbol{X_2\beta_2})]^{1[p_{1i}=1]}[1 - \Phi(\alpha_1 - \boldsymbol{X_2\beta_2})]^{1[p_{1i}=2]} \tag{38}$$

Stage 3. Degree of Market Participation

Thus far, households have faced the first hurdle which separated households into HVA producers and non-producers. Those that produce proceed to the second stage which determines their market participation outcome. Autarkic households (non-market participants), do not proceed to the third hurdle, which measures either net sales if the household is a net seller, or net purchases if the household is a net buyer. Unlike the first two stages, the estimation method will require a model that measures continuous outcomes. Additionally, the method to address continuous outcomes must deal with the truncated nature of the data where whole observations are missing depending on how they have been excluded from the hurdle model. Therefore, the third stage outcome uses log-normal regressions to measure net sales or net purchases.

As seen in equations (21)-(23), the net buyers and net sellers are defined by total market sales less total market purchases of HVA producers, where y_3 represents net buyers quantity bought as $y_3 = y_2 - y_1$, if $y_1 - y_2 < 0$, and net sellers, y_4 seen as $y_4 = y_1 - y_2$, if $y_1 - y_2 > 0$. Like the previous two stages, the log-normal equations derive their parameters using maximum-likelihood estimation. First, the distribution of y_3 and y_4 given $\boldsymbol{X_3}$ can be derived as;

$$f(y_3|\boldsymbol{X_3}, \delta_3) = \emptyset \left[\frac{\{\log(y_3) - \boldsymbol{X_3}, \delta_3\}}{\sigma^3}\right] / (y_3\sigma^3) \tag{39}$$

$$f(y_4|\boldsymbol{X_4}, \delta_4) = \emptyset \left[\frac{\{\log(y_4) - \boldsymbol{X_4}, \delta_4\}}{\sigma^4}\right] / (y_4\sigma^4) \tag{40}$$

Where y_3 and y_4 are the net quantities bought and sold and $\boldsymbol{X_3}$ are the stage three explanatory variables and its parameters to be estimated, $\emptyset$ is the standard normal probability density function and σ^j is the standard deviation of the error term for the random process determining y_j from each of the equations. The log transformation occurs within the likelihood function, so y_3 and y_4 are the levels of net quantities. Since the dependent variable in stage three is in log-form, the interpretation of the coefficients also in log-form should be, with a one percent increase in the explanatory variable we should expect a percentage change in the dependent variable equivalent to the coefficient. For explanatory variables not in log form, a one unit change in the explanatory variable changes the dependent variable by the coefficient multiplied by 100, expressed as a percentage. A one unit change in a given variable is associated with a predicted change in the dependent variable by $\beta * 100$. As in Burke et al. (2015), the explanatory variables in the estimations of each stage remain the same for the structural derivation of the triple-hurdle model. The next section outlines the econometric estimations of the conceptual framework.

4.2 Econometric Estimation

Under standard assumptions maximizing the likelihood function produces efficient, unbiased and consistent estimates of the triple-hurdle model parameters. Maximum likelihood estimates the values of a set of parameters of a model from a sample population using a function that creates a likelihood distribution. Maximum likelihood estimates are the parameter values that are most likely to have produced the observed data. Observing an independent sample $x_1, x_2, \ldots, x_n$ the log-likelihood function can be applied to various distributions, whether it be for discrete outcomes or continuous. If the observations are independent and identically distributed, the log likelihood function for a continuous random variable can be seen as;

$$logL(\theta) = l(\theta) = -\frac{n}{2}\log(2\pi\theta_2) - \frac{1}{2\theta_2}\sum_{i=1}^{n}(x_i - \theta_1)^2 \tag{41}$$

(Wooldridge 2013). Estimating the log-likelihood parameters involves maximizing this equation by setting it equal to zero and taking the first order conditions of x_i with respect to θ. This demonstrates the derivation of a log-likelihood function for a continuous random variable which will be the case in the third hurdle for net sales and net purchases volumes. However, MLE can be applied to a distribution of discrete variables, as well, which will be demonstrated in the estimation strategy for the parameters in the probit and ordered probit from the first two stages.

Given the nature of this research question, the likelihood function integrates all three stage's models into one. The rationale for creating one likelihood function for all stages is to understand how the effects from one stage can affect subsequent stage outcomes. For example, how do the effects of increased rainfall change the probability of being a net selling HVA producer, but also effect the expected value of sales for a given household?

HVA production and market participation decisions are hypothesized to be a function of demographic, farm and regional characteristics. These factors will remain the same across all stages of the triple hurdle estimations. For notational purposes, $\boldsymbol{X_1}, \boldsymbol{X_2}, \boldsymbol{X}_3$ and $\boldsymbol{X}_4$ will denote a vector of the demographic, farm and community characteristics in the corresponding stage denoted by its subscript. $\boldsymbol{X_1}$ denotes the factors determining stage one production decision, $\boldsymbol{X_2}$ represents the factors determining market participation decision, while $\boldsymbol{X_3}$ and $\boldsymbol{X_4}$ are factors determining net quantities bought for net purchasers and net quantities sold for net sellers. The empirical framework of each separate estimation defined in the previous section can now be shown within one likelihood function. The following notation $f(\boldsymbol{c}, \boldsymbol{p}, \boldsymbol{y} | \gamma_1, \gamma_2, \beta, \rho, \delta_3, \delta_4, \sigma_3, \sigma_4)$ represents the joint distribution function of the three stages outcomes given the parameters of each stage to be estimated. Thus, as in Burke et al. (2015), the full likelihood distribution and the log-likelihood function used to estimate the parameters, θ can be specified for any observation, i as;

Maximum Likelihood Function:

$$f(\boldsymbol{c}, \boldsymbol{p}, \boldsymbol{y} | \alpha_1, \alpha_2, \beta, \rho, \delta_3, \delta_4, \sigma_3, \sigma_4) = \tag{42}$$

$$[1 - \Phi(\boldsymbol{X}_1\boldsymbol{\beta}]^{1[if\ c_1=0]} * [\Phi(\boldsymbol{X}_1\boldsymbol{\beta}) \left\{ \begin{matrix} \left[\dfrac{\Phi(\alpha_0 - \boldsymbol{X}_2\boldsymbol{\beta})\emptyset\left(\dfrac{[\ln(y_3) - \boldsymbol{X}_3\boldsymbol{\delta}_3]}{\sigma_3}\right)}{y_3\sigma_3}\right]^{1[if\ p_2=0]} \\ [\Phi(\alpha_1 - \boldsymbol{X}_2\boldsymbol{\beta}) - \varphi(\alpha_0 - \boldsymbol{X}_2\boldsymbol{\beta})]^{1[if\ p_2=1]} \\ \left[\dfrac{\Phi(\boldsymbol{X}_2\beta - \alpha_1)\emptyset\left(\dfrac{[\ln(y_4) - \boldsymbol{X}_4\boldsymbol{\delta}_4]}{\sigma_4}\right)}{y_4\sigma_4}\right]^{1[if\ p_2=2]} \end{matrix} \right\}]^{1[if\ c_1=1]}$$

Log-Likelihood Function:

$$l_i(\theta) = \tag{43}$$

$$1[c_{1i} = 0]\log[1 - \Phi(\boldsymbol{X}_{1i}\boldsymbol{\beta})] + 1[c_{1i} = 1]\log[\Phi(\boldsymbol{X}_{1i}\boldsymbol{\beta})]$$
$$+ 1[p_{2i} = 0]\ (\log[\Phi(\alpha_0 - \boldsymbol{X}_{2i}\boldsymbol{\beta})] - \log(y_{3i}) - (\frac{1}{2})\log(\sigma_3^2) - (\frac{1}{2})\log(2\pi)$$
$$- \frac{1}{2}\left(\left[\frac{\{\log(y_{3i}) - \boldsymbol{X}_{3i}\boldsymbol{\delta}_3\}^2}{\sigma_3^2}\right]\right)$$
$$+ 1[p_{1i} = 1]\log[\Phi(\alpha_1 - \boldsymbol{X}_{2i}\boldsymbol{\beta}) - \Phi(\alpha_0 - \boldsymbol{X}_{2i}\boldsymbol{\beta})]$$
$$+ 1[p_{1i} = 2]\log[1 - \Phi(\alpha_1 - \boldsymbol{X}_{2i}\boldsymbol{\beta}) - \log(y_{4i}) - \left(\frac{1}{2}\right)\log(\sigma_4^2) - \left(\frac{1}{2}\right)\log(2\pi)$$
$$- \frac{1}{2}\left(\left[\frac{\{\log(y_{4i}) - \boldsymbol{X}_{4i}\boldsymbol{\delta}_4\}^2}{\sigma_4^2}\right]\right)$$

Here, $\Phi(\cdot)$ represents the standard normal cumulative density function; $\emptyset$ denotes the standard normal probability density function; ρ represents the stage one parameters of $\boldsymbol{X}_1$; α_0 and α_1 are used to represent the limits in order to define the categorical outcomes of the ordered probit; β represents the parameters for stage two on $\boldsymbol{X}_2$; δ_3 and δ_4 represent the parameters for the third stage for y_3 and y_4. Where it reads, $if\ p_2 = 0$, 1, or 2, this refers to the ordinal outcome of zero to represent net buyers, one for autarkic, and two denotes net sellers. Lastly, σ_3 and σ_4 are the error variance for the third stage net quantities bought and sold, $\ln(y_3)$ and $\ln(y_4)$.

Burke et al. (2015) points out that the log-likelihood equation (43) can be estimated simultaneously, as well as separately due to the separability feature of the likelihood function.

This allows for each stage to be estimated separately. If estimated separately, the following steps are required;

Estimation Steps:

1. ρ can be estimated using a probit regression of c_1 on $\boldsymbol{X}_1$;
2. β can be estimated using an ordered probit by regressing p_2 on $\boldsymbol{X_2}$ if $c_1 = 1$;
3. δ_3 can be estimated by regressing $\log(y)_3$ on $\boldsymbol{X_3}$ using only the observations from $p_2 = 0$;
4. δ_4 can be calculated by regressing $\log(y)_4$ on $\boldsymbol{X_4}$ using the observations from $p_2 = 2$.

For valid inference of standard errors using separate ML estimation, Burke stipulates that the error terms in all equations are uncorrelated conditional on all explanatory variables. If the condition does not hold, separately estimating the equations will result in biased coefficients.

The test for this condition follows a Heckman test for selection bias (Burke et al. 2015; Wooldridge 2010). The test proceeds by predicting the Inverse Mills Ratio (IMR) around the dependent variable outcome and including it as an explanatory variable in the estimate of the subsequent stage model. For example, the IMR_c will be calculated around the probability of being a producer of HVA in stage one, the IMR_c will then be included in the second stage ordered probit as an explanatory variable. If the errors are conditionally uncorrelated, IMR_c should have no explanatory power in the second stage estimation. A simple t-test can test this condition under the hypothesis that $IMR_c = 0$. If its coefficient is statistically different than zero, the null hypothesis is rejected and estimates would be biased if the IMR were excluded. If the null cannot be rejected, the other estimates are only unbiased and consistent when the IMR is included, but standard statistical inference is not valid because you have included a predicted regressor. Nevertheless, when the null cannot be rejected, then one can proceed to the second stage. The same process is implemented on the next stage, gathering the IMR from the stage two ordered probit around the probability of being a net seller or net buyer and estimating them as an explanatory variable in the following stage equation using ordinary least squares. The same t-test procedure is applied at stage two to determine if inference can be made without bias. It should be noted that these procedures are conducted using only the appropriate observations that carry over to subsequent stages.

Given the data structure used in the study, simultaneous maximum likelihood estimation of all three stages does not converge for parameter estimates. Therefore, each stage is estimated separately and satisfies the assumption of uncorrelated errors between all stages for valid inference. Burke notes that interpretation of each explanatory variable depends on the effects from all equations throughout the model. For example, for any observation, four unconditional probabilities can be calculated, as can the partial effect on these probabilities with respect to each explanatory variable. Among the many outcomes of interest in the triple-hurdle model, key results include:

$$Pr(cultivating\ HVA) = Pr(c_{1i} = 0|\boldsymbol{X_i}) = 1 - \Phi(\boldsymbol{X}_{1i}\boldsymbol{\rho}) \tag{44}$$

$$Pr(net\ buying\ producer) = \Pr(c_{1i} = 1, p_{2i} = 0|\boldsymbol{X_i}) = \Phi(\boldsymbol{X}_{1i}\boldsymbol{\rho})\Phi(\alpha_0 - \boldsymbol{X}_{2i}\boldsymbol{\beta}) \tag{45}$$

$$Pr(autarkic\ producer) = \Pr(c_{1i} = 1, p_{2i} = 1|\boldsymbol{X_i}) = \Phi(\boldsymbol{X}_{1i}\boldsymbol{\rho})(\Phi(\alpha_1 - \boldsymbol{X}_{2i}\boldsymbol{\beta})\Phi(\alpha_0 - \boldsymbol{X}_{2i}\boldsymbol{\beta}) \tag{46}$$

$$\Pr(net\ selling\ producer) = \Pr(c_{1i} = 1, p_{2i} = 2|\boldsymbol{X_i}) = \Phi(\boldsymbol{X}_{1i}\boldsymbol{\rho})(1 - \Phi(\alpha_1 - \boldsymbol{X}_{2i}\boldsymbol{\beta})) \tag{47}$$

In addition to the abovementioned probabilities, unconditional expected values can be calculated from the likelihood function for net sales and net purchases for all observations. Burke explains how this implies the expected values are not conditional on the values of the dependent variables, such as the household being a producer or a market participant (Burke et al. 2015). For each observation, the derivation can be seen as:

$$E(net\ purchases) = E(y_{3i}|\boldsymbol{X}_i) = \Phi(\boldsymbol{X}_{1i}\boldsymbol{\rho})\Phi(\alpha_0 - \boldsymbol{X}_{2i}\boldsymbol{\beta}) * exp(\boldsymbol{X}_{3i}\delta_3 + \sigma_3^2/2) \tag{48}$$

$$E(net\ sales) = E(y_{4i}|\boldsymbol{X}_i) = \Phi(\boldsymbol{X}_{1i}\boldsymbol{\rho})\Phi(\boldsymbol{X}_{2i}\boldsymbol{\beta} - \alpha_1) * exp(\boldsymbol{X}_{4i}\delta_4 + \sigma_4^2/2) \tag{49}$$

Average partial effects are calculated for the first two stages, while the third stage log-normal regression output can be interpreted as conditional average partial effects, according to Burke et al. (2015).

The last quantities of interest are the partial effects for each stage of the model. Probit models traditionally base inference on marginal effects because of the non-linear nature of the model, although partial effects are calculated because they are derived considering hypothetical, interaction terms. The partial effect depends on parameters and explanatory variables from all of the stages. These can be derived as follows:

$$\frac{\partial E(y_{4i}|\boldsymbol{X_i})}{\partial x_{ki}} = \boldsymbol{\rho}_k \emptyset(\boldsymbol{X}_{1i}\boldsymbol{\rho})\Phi(\boldsymbol{X}_{2i}\boldsymbol{\beta} - \alpha_1) * \exp\left(\boldsymbol{X}_{4i}\delta_4 + \frac{\sigma_4^2}{2}\right) + \beta_k \Phi(\boldsymbol{X_{1i}\rho})\emptyset(\boldsymbol{X}_{2i}\boldsymbol{\beta} - \alpha_1) * \exp(\boldsymbol{X}_{4i}\delta_4 + \sigma_4^2/2) + \delta_{4k}\Phi(\boldsymbol{X}_{1i}\boldsymbol{\rho})\Phi(X_{2i}\boldsymbol{\beta} - \alpha_1) * \exp(\boldsymbol{X}_{4i}\delta_4 + \frac{\sigma_4^2}{2}) \quad (50)$$

From equation 50, we can derive the partial effect of a continuous variable, denoted at $\boldsymbol{X}_k$, on the unconditional expected value of net sales or net purchases. For ease of interpretation, the partial effects are averaged across the sample, including the partial effects on the unconditional expected value, as in Burke et al.(2015). Additionally, we can estimate the partial effects of each explanatory variable on the probability of an HVA producing household being a net seller. The standard errors of the average partial effects are calculated using the bootstrap technique that relies on random sampling with replacement.

Estimation of Burke's et al. (2015) triple-hurdle model applied to panel data uses a pooled estimator with maximum likelihood estimation. When performing the estimations, households are clustered to provide robust standard errors, which will account for autocorrelation resulting from inter-temporal dependence between observations.

Hypotheses:

This research hypothesizes that,

1) Access to information, infrastructure, inputs, capital, and crop prices, are significant determinants of HVA cultivation and market participation,

2) The same processes that influence a farmer to cultivate HVA increase the probability of being a net seller in the market.

The hypotheses will be tested based on the statistical significance of the coefficients from the model estimations being different than zero. The conclusions to be drawn from the results that test these hypotheses will provide a deeper understanding of whether common policy approaches to promote market participation may have further-reaching effects than anticipated. Dually, this can inform policy-makers if policies should be implemented that focus on market participation and the adoption of HVA separately.

Based on previous literature, access to credit, inputs, information, capital and infrastructure constraints are the key hypothesized determinants of crop diversification. Since Uganda has tried to promote policies that broaden its export base and increase smallholder commercialization, exposure to extension services which is believed to transfer such information, is hypothesized to be a key determinant of diversification. Many HVA products are considered capital intensive, therefore access credit may facilitate the startup costs of commencing HVA production. Ownership of productive technologies has also been considered an enabling factor in the decision to commence for the same reason. Households that do not use improved seed have increased production risk and may choose to prioritize home consumption through few crops, therefore its adoption is believed to have a positive relationship to crop diversity. Hired labor, another input, which increases household working capacity, is also widely cited to positively impact diversity. Table 4.1 shows expected signs on HVA production decision and its probability of being a net seller, conditional on being a HVA producer:

Table 4.1: Expected Sign of Coefficients on Dependent Variable

Explanatory Variable	Decision to Cultivate HVA	Pr(Net Seller)
Ln(land)	+	+
Male head	+	+
Head education	+	+
Head age	-	+
Received credit	+	+
Ln(productive assets val.)	+	+
Urban area	-	-
Distance to market	-	-
Distance to road	+	-
Distance to population center	-	-
Tech endowment	+	+
Improved seed	+	+
Annual average rainfall	+	+
Plot elevation	+	-
Hired labor	+	+
Adult equivalents	+	+
Ln(Dist. Beans price)	-	+
Ln(Dist. Cassava price)	-	+
Ln(Dist. Maize price)	-	+
Ln(Dist. Coffee price)	+	+

CHAPTER 5: DATA AND VARIABLES DESCRIPTION

5.1 Dependent Variables

The triple-hurdle model, will use a total of four different dependent variables. The first being the decision to cultivate HVA, representing a binary decision of zero to indicate a non-producer of HVA and one, to indicate that the household does produce HVA. Stage two outcome uses an ordered probit, taking on three values; zero, one, or two to sort households into net buyers, autarkic, and net-sellers. Third stage dependent variables are net quantities of purchases and sales, both in log-form. Table 5.1 shows their definitions and the values which they can take on, as well as their mean sample values at the starting panel wave in 2009 and last wave in 2012.

Table 5.1: Dependent Variables

Dependent Variables	Definition	Mean 2009	Mean 2012
Probit: HVA	$\Pr(Cultivate\ HVP = 0, 1)$	0.524	0.609
Ordered Probit: NS, A, NB	$\Pr(NS, Aut, NB) = 0,1,2$	1.649	1.801
Ln(Net Purchases)	$\ln(sales - purchases) * -1$	11.761	12.236
Ln(Net Seller)	$\ln(sales - purchases)$	12.163	12.522

Source: World Bank LSMS n=1,968 in 2009/2010, n = 2,117 and n = 2,032 in 2011/2012

Table 5.1 shows that the probit takes on the values of either 0 or 1, to indicate if the household produces HVA. The ordered probit can take the values of 0, 1, 2 to separate households into their respective market participation categories. Ln(net purchases) shows the log of sales minus purchases multiplied by -1 to obtain a positive value if the household is a net purchaser in the market and HVA producer. Ln(net sales) provides the log of sales minus purchases if the household is a net seller and an HVA producer. The mean values of the probit from 2009 to 2012 show that 52.4% of the sample were HVA producers, while in 2012 60.9% became producers. The ordered probit mean values show that a there was an increase in the number of net sellers from 2009 to 2012 illustrated by the increase from 1.64 to 1.80. Of net sellers and net buyers who produce HVA, net sellers sold more and net buyers bought more from 2009 to 2012.

The stage one probit that separates HVA producers and non-producers depends on a specified set of HVA products. HVA are considered cash crops, as well as horticulture. One crop that is an exception in the horticulture list are plantains, which are a staple crop of Uganda. Plantains are cultivated by 47% of all farmers and provide the greatest amount of caloric intake of all Ugandan crops. Their prevalence makes them a crop with low economic returns in Uganda and are less frequently traded. Given the nature of the study – to analyze the decision to cultivate HVA and its marketing outcomes, they are left out of the selected list HVA products.

From the three waves of survey panel data from the World Bank's LSMS 2009/2010, 2010/2011, and 2011/2012, Ugandan farmers who cultivate any of the following crops are considered HVA producers: cabbage, tomatoes, carrots, onions, pumpkins, dodo, eggplants, sugar cane, cotton, tobacco, oranges, paw paw, pineapples, mango, jackfruit, avocado, passionfruit, coffee, cocoa, tea, ginger, curry, oil palm, vanilla, black wattle. As indicated in the table, in 2009 35.1% are HVA producers, while 37.8% are producers in 2012. Contrarily, crops that do not constitute HVA from the survey data are maize, finger millet, sorghum, wheat, barley, rice, field peas, cow peas, chick peas, pigeon peas, soyabeans, sunflower, sesame, yam, coco yam, and Irish potatoes, beans, banana, cassava, sweet potatoes, and groundnuts. Over the panel years, market participation of sellers has also increased. Over the time period of the sample, 2009-2012, households marketing their products has shown a gradual increase from 74.4% to 80.2%.

5.2. Explanatory variables

Conventional wisdom argues that agricultural household decisions are a function of household (demographic), farm, and community characteristics (Mofya-Mukuka et al. 2016). Other studies such as Turner (2014) and Burke et al. (2015) have divided the determinants into different sub-categories, such as household and farm-level characteristics, market prices and market constraints. For an in depth view of the explanatory variables used in these analyses, determinants are divided into household, farm, and regional characteristics, along with market prices and market constraints. All of the used variables and their calculations are from the data offered from the World Bank's LSMS survey of Uganda 2009-2012. The explanatory variables used in the analyses are:

Household-Level Characteristics:

These variables include those related to the characteristics of the household members such as human capital and life-cycle stage of the farm-household (Benin 2004). Life cycle of the farm is often associated with the age of household head. This serves as a proxy for farming experience and managerial skill, but also has implications on the decision to adopt new crops. It is expected that the age of the household head has a direct relationship with farm diversity because younger households may be more amenable to experiment with different crops and varieties, where older households may be expected to be the opposite, with greater propensity to rely on traditional practices (Van Dusen 2000).

The effect of being male versus being female is expected to be positive on crop diversification. Female farmers generally face greater social barriers than men (Farnworth, Akamandisa, and Hichaambwa 2011). This is the result of societal gender roles and because male household heads often obtain higher levels of education which is related to greater access to farming technology services, credit and selling of produce (FAO) which has contrasting outcomes for agricultural productivity, as well. The household head's gender is captured with use of a dummy variable indicating one if male and zero if female. Similarly, education level of the household head is positively being expected to be positively associated with farmer's ability to access information and to meet and adopt more complex management requirements for particular crops (Rehima et al. 2013). Another widely used meter of human capital is the number of full-time adult equivalents in the household which represent available non-hired labor.

To summarize, the household/demographic characteristics used as explanatory variables in the estimations are age, gender and level of education of the household head, as well as full-time adult equivalents.

Farm-Level Characteristics:

Different measures that serve as proxies for household wealth are often cited as factors which influence crop diversification. This is argued to be the case due to farmers typically needing some form of support with working capital in order to diversify (Carter 2000) (Mofya-Mukuka & Hichaambwa 2016). Household income is hypothesized to be associated with crop diversification decisions, however it presents an endogeneity problem because it is a function of land allocation. Instead, many agricultural studies use the household's value of productive assets in log form. This study uses this approach – log value of owned productive assets. This is calculated by aggregating all productive assets that could be related to crop diversification decisions. Assets such as televisions, computers, radios, electronic equipment may sound irrelevant, but are included in the calculation of productive assets because many farmers obtain information about crops from such sources. Additionally, it includes working assets such as tractors, motor vehicles, generators, among others are included in the calculation.

Total household landholdings in log-form is included as an explanatory variable. Landholdings are expected to positively affect the probability of a household diversifying and adopting HVA because households with greater amounts of land have more to work with and are more likely to produce a crop for the market once their consumption needs are met (Turner 2014). However, a non-linear or, inverse relationship may be present between the decision to diversify and land size. Larger farms may be expected to specialize because they have more working capital.

Bellemare (2012) offers several explanations of this inverse relationship. One seminal account draws from Sen (1966), describing that in developing countries where working capital is scarce, households with smaller farm sizes simply had more labor per land unit than larger farms. Another explanation for the inverse relationship is related to the analyst's omitted variables problem. Unobserved factors such as soil quality are, on a very rare basis, included in researcher's estimations for this relationship. Farmers tend to cultivate their most fertile land first, then expand cultivation into areas of lesser soil quality which makes larger farms appear less productive (Bellemare 2012). The last explanation deals with the problem of a spurious inverse relationship due to measurement error.

Inputs such as improved seed and use of hired labor are used as explanatory variables. Use of hired labor is an additional variable to represent labor availability, which increases the working capacity of the household. Since HVA can be capital intensive, additional labor is hypothesized to facilitate HVA adoption. Households that do not use improved seed can have increased production risk and may choose to prioritize home consumption through few crops, therefore its adoption is believed to have a positive relationship to crop diversification decisions. Both are controlled for with the use of a dummy variable to indicate whether the household hired labor or used improved seed.

Regional Characteristics:

Annual total average rainfall may have various outcomes on crop diversification decisions. Literature suggests that farmers in developing countries are often risk averse and crop diversification is a commonly cited method to hedge against price and production risk (Bezabih and Sarr 2012). This decision comes from insuring that the household can have income from market-sold crops in the event that household production is low. Annual total average rainfall at the district level is used for the analysis.

Population density in developing countries can have varying effects for agricultural productivity and diversification. Uganda is the ninth most densely populated country in Africa, therefore urban areas, especially are expected to have high density. Consequently, households in urban versus rural areas can have different outcomes with respect to crop choices. Additionally, in urban areas, it is more likely that households have members engaged in off-farm labor. Birthal et al. (2007) states that a household's occupation is a key determinant of crop choices. Households with off-farm occupations may be more likely to cultivate crops that are less labor-intensive due to competing uses of labor. Like variable rainfall, the decision to venture into HVA may play a role as an insurance mechanism against variable production in highly densely populated areas and less of a role in areas of less density. A binary indicator of rural and urban households is included, but does not fully address true population density.

Uganda is mountainous and elevations can vary, which makes some crops more feasible than others (Gerold 2004). In areas that have agroecological features less suitable for crop production, such as regions of variable rainfall or in high elevations, crop diversification is seen as a risk mitigation strategy by diversifying into crops that use less resources. Therefore, greater elevation (meters above sea level) are believed to be positively related to crop diversification decisions. Arabica coffee, for instance, is grown at higher elevations of Uganda and may therefore positively influence the probability of farmers being an HVA producer. Elevation is reported at the household-level.

Market Prices:

Changing diversification patterns is widely believed to reflect changing infrastructure and market signals (Kurosaki 2003). Higher profitability is the key driver to induce crop diversification. Perfect knowledge is not available to farmers and expected prices are a widely used proxy used for price, although this analysis uses current prices in order to retain all panel waves. Average maize, cassava, coffee, and beans prices at the district-level are included. This may represent an endogeneity problem by including a portion of the household's price in the district calculation because individual behavior can influence its own selling price, but it is likely to be largely reduced by using the district average (Turner 2014). Maize, cassava, and beans, which are substitutes for HVA, are produced with high frequency in the sample and their prices are hypothesized to have inverse relationships with the probability of cultivation HVA and the HHI. These variables are calculated by averaging the amount received per kilogram at the district-level and are in log-form to improve the data fit.to reduce skewness in the distribution to improve data fit.

Constraints:

Returns to crop diversification depend on the accessibility and availability of various infrastructure facilities. Irrigation, electricity, transportation, storage and accessibility of markets encompass the bulk of infrastructure constraints with respect to diversification (Abro 2012). This analysis uses distance to the nearest market, urban center and road as the constraining infrastructure characteristics. These partially represent transfer costs, which include transaction costs plus transportation costs. For example, if a household is close to a market and has a paved road to access it, its transport costs are greatly reduced compared to the isolated farmer without poor travel passages. Transaction costs, which are associated with institutional characteristics of the market are not captured in this data. Incentives to become more efficient and increase agricultural productivity become greater when transfer costs are reduced, believed to incentivize HVA production.

Birthal (2007) highlights the importance of extension services because, unlike staple crops, information requirements of HVA products tend to be high. Obtaining access to information about different crops and management practices encourage diversification and supplies farmers with new farming technologies that impact productivity. For analysis, only extension services, which are often offered by agricultural extension networks is used as an explanatory variable, but radios, television and other information channels have been used before. Extension service contact may be impacted by the infrastructure constraints already in place, presenting an endogeneity problem. However, it is unlikely that there are significant changes in the infrastructure development across the panel waves, which should not cause bias in the estimates, although both are included to avoid any omitted variable problems.

Financial services are often scarce for many rural farmers in lesser developed countries (Birthal et al. 2007). Often times, such is needed to purchase or make in initial investment in inputs in order to change production. Moreover, the cultivation of many HVA crops is capital intensive and obtaining credit may facilitate the high start-up costs. Credit access should thus be positively related with the uptake of HVA. The share of households in a district receiving credit is used as a proxy for credit availability (Burke et al. 2015). If a household receives any form of credit from an official agency, they qualify as a credit receiving household. Credit-receiving households are aggregated at the district-level and divided by the aggregate number of households in the district.

5.3. Descriptive Statistics

Below in table 5.2 provides a general overview of the main variables that will be used in the econometric modelling. Their average values across, standard deviations, minimum and maximum values are reported across the entire sample. UGX denotes Ugandan Shillings, MASL denotes meters above sea level, Ha is hectares and Km represents kilometers.

Table 5.2: Dependent Variables, Household and Regional Characteristics

Variable	Unit	Obs.	Average Values	Std. Dev.	Min	Max
Dependent Variables						
HVP Producer	(1 = yes)	6,104	0.36	0.5	0	1
NS, Aut. NB	Category	8,688	1.8	0.5	0	2
Ln(Net Sales)	UGX	4,110	12.4	1.6	3	18.4
Ln(Net Purchases)	UGX	442	12.1	1.3	7.9	15.4
Household and Farm Characteristics						
Male Head	(1=yes)	7,113	0.7	0.5	0	2
Ln(Household Land)	Ha	5,593	0.8	0.6	0	5.8
Adult Equiv.	Adults	7,113	3.2	1.9	0	20
Ln(Prod. Assets)	UGX	6,190	9.9	1.6	0	15.2
Hired Labor	(1 = yes)	6,603	0.6	0.5	0	1
Improved Seed	(1 = yes)	5,915	0.1	0.3	0	1
Tech Endowment	(1 = yes)	5,657	0.4	0.5	0	1
Head Age	Years	7,111	46.8	15.1	14	100
Head Education	Years	5,703	23.7	15.8	10	99
Regional Characteristics						
Received Credit	(%)	8,898	0.1	0.1	0	0.7
Urban	(1 = yes)	7,129	0.2	0.4	0	1
Distance Pop Center	Km	7,107	22.5	18.2	0.1	102
Distance to Market	Km	7,107	30.6	19.8	0.1	116.2
Distance to Road	Km	7,107	7.5	7.5	0	41.4
Ann Avg. Rainfall	mm/year	7,107	1129.7	173.7	514	1655
Elevation	(MASL)	7,107	1234.5	238.7	621	2396
Ln(Dist. Coff. price)	UGX	3,623	8.4	2.9	2.8	14.4
Ln(Dist. Beans price)	UGX	4,999	8	3.1	2.5	13.6
Ln(Dist. Maize price)	UGX	5,976	7.8	3.3	1.9	14.2
Ln(Dist. Cass. price)	UGX	4,723	5.4	2	0.8	13.8

Source: World Bank LSMS 2009-2012. *n* varies based on data availability. (Head education is on a scale unequal to grade level). (UGX stands for Uganda Shilling)

5.4 Data

This research uses nationally representative data for Uganda from the World Bank's Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA), which was implemented in conjunction with The Uganda National Panel Survey (UNPS) and Uganda Bureau of Statistics (UBOS). Data consists of three panel waves from 2009 to 2012 where each panel wave contains data over a twelve-month period. Each panel wave is broken into 2009/2010, 2010/2011, and 2011/2012.

The LSMS surveys cover a variety of topics on demographics, labor, income and consumption dynamics at the household-level, among other welfare indicators of Uganda. Its survey aims have been primarily to provide annual information to monitor various economic indicators used to inform and evaluate policy decisions. Due to attrition, new households are added annually which results in an unbalanced panel set. This study uses the household survey, agricultural survey and the geospatial data provided. Much of Uganda has two rainy periods and calculations were aggregated on an annual basis.

In 2005/2006, a baseline survey conducted by the Uganda National Household Survey (UNHS) with the UNPS interviewed 3,123 households distributed across 322 enumeration areas (EA) selected from a larger pool of 783 enumeration areas. In the 2009/2010 survey, the sample size became 2,975, in the 2010/2011 wave is 2,716, and in 2011/2012 is 2,850. Within each stratum, the UNPS EAs were randomly selected from UNHS EAs with equal probability to comprise a nationally representative sample. The strata of representativeness from the UNPS includes Kampala City, other urban areas, central rural, eastern rural, western rural, and northern rural (World Bank LSMS).

Attrition:

Survey attrition, if not adequately accounted for, can result in biased estimates because they are not representative of the national sample. Many longitudinal household surveys are troubled with attrition, especially in developing countries where communication infrastructure is less advanced, making it difficult to precisely track all the household respondents across the panel waves, as is the case in the dataset. In the data set, it was reported from the LSMS that attrition arose primarily from households moving and being unable to locate, mortality, disintegration (household members part ways and none of them remain at the original location), or refusal of interview.

For tracking of the households in all years, the aim was to identify and survey all 3,123 original panel households. In the baseline survey, conducted in 2005/2006, two households in each EA were randomly selected to track baseline individuals that moved away from their original locations since 2005/2006. The UNPS tracked the sub-sample with the intention to recalibrate the size and composition of the original sample to compensate for attrition. The attrition rate from 2005/2006 to 2009/2010 was 15.7% for households and 20.5% for individuals. For the following years, no explicit calculation for the attrition rate was offered from LSMS and UNPS. By observing the original households from 2009/2010 to the subsequent years, the calculation can be made. From the base year to 2010/2011, the attrition rate is 11.02%, and from the base year to 2011/2012 is 13.04%, which is the overall attrition rate. The construction of the survey weights provided from the LSMS UNPS survey for Uganda account for several causes; an attrition correction factor to correct for households that were unable to be surveyed and the incorporation of new households in the sample to account for the changing population which is accomplished by adding split-off households to recalibrate the sample size. The household panel weights are adjusted to correct for attrition in each consecutive year using predicted response probabilities from a logistic regression model. The methodology of the UNPS follows that of Rosenbaum and Ruben (1984). This analysis uses the household probability weights with the intention of providing unbiased, nationally representative parameter estimates for Uganda.

Incomplete Data:

Despite the stated sample size by the World Bank, of those reported figures, in 2009-2010 68.2% of the households reported the size of their landholdings. In 2010-2011, 72% reported their landholding size, and in the 2011-2012 wave, 69.9% reported. Many of the calculations make use of the reported household landholding sizes, making the sample used in estimations a sub-sample. Aside from unreported landholding sizes, other variables have reporting issues, as well, but not to the same extent as landholding size. Statistical software programs, such as STATA 14 (used for all calculations in this analysis) that perform econometric estimations, require all values of estimated variables to be reported if they are going to be included in the estimation sample. Therefore, estimation samples may decline significantly for such reasons. Missing values of variables can become a concerning issue because it can be a source of estimate bias.

To account for any potential problems that could arise from the omitted observations in the sample, imputed means are calculated for missing values of continuous variables to provide a separate, parsimonious model. Although this method has its drawbacks, such as reduced variance and can disrupt the correlation between variables, it is meant to provide a robustness check on the original sample used for estimation. Tables of both estimations will be provided.

CHAPTER 6: RESULTS

6.1 Bivariate Relationship Analysis

To foreshadow the analysis, bivariate analysis is provided on the Pearson linear correlation coefficient between the explanatory variables and the dependent variables in each stage of the triple-hurdle in table 6.1. This will aid in the interpretation of the results to come. Following the triple hurdle estimation, average partial effects for the key variables of interest are provided, along with a brief analysis of the common marketing channels Ugandan smallholder farmers use for HVA products to provide greater context.

It should be noted that, in the estimations, the number of observations may decline severely due to household observations with incomplete information. HVP represents the first stage binary outcome of whether or not households are HVA producers. NS, Autarkic, NB denotes the second stage ordered probit, determining whether households are net buyers, autarkic, or net sellers in the market. Ln(Net Sales) and Ln(Net Purchases) represents net sales if the household is a net seller and net purchases if the household is a net purchaser. In parentheses are the t-statistics indicates if there is a statistically significant linear relationship between the variables at an alpha level of 5%, which will be shown by an asterisk next to the correlation coefficient.

Table 6.1: Correlations Between Dependent and Explanatory Variable

	HVP	NS, Autarkic, NB	Ln(Net Sales)	Ln(Net Purchases)
Male Head	0.077*	0.023	0.219*	-0.030
	(0.000)	(0.055)	(0.000)	(0.518)
Ln(Household Land)	0.046*	0.048*	0.295*	-0.160*
	(0.000)	(0.000)	(0.000)	(0.001)
Adult Equiv.	0.075*	0.002	0.177*	0.169*
	(0.000)	(0.882)	(0.000)	(0.000)
Ln(Prod. Assets)	0.105*	0.021	0.312*	0.247*
	(0.000)	(0.073)	(0.000)	(0.000)
Hired Labor	0.000	0.084*	0.167*	0.150*
	(0.025)	(0.000)	(0.000)	(0.001)
Improved Seed	0.051*	0.006	0.072*	0.006
	(0.000)	(0.668)	(0.000)	(0.896)
Tech Endowment	0.011	-0.035	0.053*	0.088
	(0.410)	(0.147)	(0.001)	(0.065)
Head Age	0.071*	-0.033*	-0.077*	-0.035
	(0.000)	(0.004)	(0.000)	(0.462)
Head Education	0.009	0.000	0.099*	0.254*

	(0.543)	(0.978)	(0.000)	(0.000)
Received Credit	-0.025*	0.070*	0.079*	-0.038
	(0.044)	(0.000)	(0.000)	(0.413)
Urban	-0.064*	0.011	-0.0261	0.183*
	(0.000)	(0.354)	(0.090)	(0.000)
Distance Pop Center	-0.064*	-0.037*	0.021	-0.168*
	(0.000)	(0.001)	(0.175)	(0.000)
Distance to Market	-0.011	-0.085*	0.014	-0.155*
	(0.384)	(0.000)	(0.353)	(0.001)
Distance to Road	0.126*	0.046*	0.021	-0.157*
	(0.000)	(0.000)	(0.173)	(0.001)
Ann Avg. Rainfall	0.055*	0.115*	-0.113*	0.089
	(0.000)	(0.000)	(0.000)	(0.057)
Elevation	0.055*	0.050*	0.077*	0.013
	(0.000)	(0.000)	(0.000)	(0.776)
Ln(dist Coff price)	0.108*	-0.001	-0.022	0.207*
	(0.000)	(0.942)	(0.258)	(0.006)
Ln(dist Beans price)	-0.062	0.008	-0.040*	-0.028
	(0.000)	(0.584)	(0.019)	(0.652)
Ln(dist Maize price)	0.024	0.059*	-0.026	0.091
	(0.081)	(0.000)	(0.107)	(0.076)
Ln(dist Cassava price)	-0.031*	0.026	-0.020	-0.004
	(0.041)	(0.065)	(0.263)	(0.944)

Source: World Bank LSMS 2009/2010 *n = 1,752*

With the simple t-test, tech endowment, which indicates if the household has been exposed to extension services, does not have a statistically significant linear relationship with households that cultivate HVA. Most notably, land and productive assets ownership show significant relationships in most if not all stages with the dependent variables. This result is not unexpected, as these are both variables commonly theorized to increase with commercialization. Surprisingly, distance to the nearest road has a significant, but positive correlation with HVA producers, which is inconsistent with hypothesis. This would indicate further access to roads is positively correlated to HVA producers. Contrarily, distance to the nearest population center shows an inverse correlation with HVA producers, as expected. This result implies closer distances to population centers increase with households that cultivate HVA.

Common Marketing Channels of HVA:

To provide deeper context into Ugandan agricultural marketing, table 6.3 provides the common marketing channels for HVA that farmers face. Government buyers and local cooperatives have a relatively small presence in Uganda for HVA products, comprising less than 1% of the marketing channels. Private traders in local markets take the lion's share of HVA purchases, indicating over half of the purchases, reaching 65.03% in 2009. Private traders in the district market and the market consumer results are relatively balanced, hovering around 9-20%.

Table 6.2: Marketing Channels of HVA

Year	Gov/Local Coop	Private Trader in Local Village/Market	Private Trader in Dist. Market	Consumer at Market	Neighbour/ Relative	Other
2009-2010	0.61%	65.03%	11.54%	13.02%	6.54%	3.27%
2011-2011	0.41%	66.59%	9.37%	16.54%	6.13%	0.96%
2011-2012	0.11%	55.78%	17.32%	19.98%	6.23%	0.58%

Source: Uganda LSMS-UNHS survey data, *n* = 1,371 for 2009-2012 (In panel form).

Local neighbors or relatives are also marginal buyers of HVA products from producers, but only comprises 6-7%. This finding stresses the importance of local markets. Their access can be improved by reducing transaction costs, in ways such as increasing their proximity or prevalence, road access, and ease of general transportation. Given the data availability of this survey, it is not clear as to where HVA products are distributed beyond the marketing channels mentioned above.

6.2 Triple Hurdle-Model

Results from the triple-hurdle estimation are presented in table 6.3. Time dummies for all but the base year are included in estimations to allow for varying intercepts and coefficients between time periods. To test for conditionally uncorrelated errors between the stages, the IMR is generated around the probability of being an HVA producer and is included in the second stage estimation as a regressor. Secondly, the IMR is then calculated from around the stage two market participation outcomes, then included in stage three as a regressor. In both cases, they are statistically insignificant, as seen below. The resulting coefficient and p-value from a simple t-test to allow us to conclude there is no selection bias between the stages of estimation. The coefficient of the IMR when included in the consequent second and third stage estimations for net sales are the following:

Stage 2 Market Participation Outcome: $\beta_1 IMR_1$ = *-3.944; p-value = 0.413*

Stage 3 Net Sales: $\beta_2 IMR_2$ = *1.705; p-value = 0.367*

Considering the lack of statistical significance of the Inverse Mills Ratio in explaining market participation outcomes and net sales, the IMR is omitted from the estimates in the triple hurdle.

The estimation for net purchases in the third stage, conditional on being a producer and net buyer, has few observations, along with few statistically significant coefficients. The data structure under the triple-hurdle indicates that, of those who produce HVA, they rarely result in being a net buyer. Considering this, the estimation for net purchases is omitted from the results because no meaningful inference can be made.

The results of the triple-hurdle model in table 6.3 are not marginal effects due to the non-linear nature of the likelihood function used for estimation. The interpretation should therefore be limited to the sign and statistical significance associated with the probability of the results. For example, a positive coefficient for household land size in stage one indicates greater likelihoods of being a producer of HVA are associated with increasing land sizes. Stage two ordered probit coefficients can be interpreted similarly, with a small alteration; greater probabilities of being a net seller are associated with increases in the coefficients, while there are greater probabilities of being a net buyer as the coefficients decrease, conditional on being a HVA producer (Burke et al. 2015). Stage three results provide estimates for net sales quantities, conditional on being a HVA producer and net seller. Beneath the coefficients are the standard errors. Asterisks indicate statistical significance at different levels of alpha.

Table 6. 3: Triple Hurdle Estimation

Explanatory Variables	**Stage 1: Production Decision**	**Stage 2: Market Participation**	**Stage 3: Net Sales**
Ln(Land Size)	0.211**	0.347**	0.692***
	(-0.0823)	(-0.136)	(-0.112)
Head Sex	-0.15	-0.475***	0.268*
	(-0.126)	(-0.178)	(-0.15)
Dist. % Rec Credit	-2.210***	-1.097	0.112
	(-0.787)	(-1.14)	(-0.866)
Ln(Productive Assets)	0.0684	0.0871	0.219***
	(-0.0436)	(-0.0663)	(-0.0651)
Head Education	-0.00165	-0.0146***	0.00161
	(-0.00281)	(-0.00358)	(-0.00424)
Urban	-0.492***	0.178	-0.115
	(-0.188)	(-0.217)	(-0.202)

Dist. Pop. Center	-0.00447	0.0111	-0.00763
	(-0.00504)	(-0.00813)	(-0.00607)
Dist. Market	0.0153**	0.0164	0.0205**
	(-0.0077)	(-0.0128)	(-0.0104)
Dist. Road	0.000562	-0.00870**	-0.00357
	(-0.00317)	(-0.00415)	(-0.00369)
Improved Seed	0.399***	0.568***	0.195
	(-0.132)	(-0.213)	(-0.149)
Head Age	0.00477	0.00296	-0.0108***
	(-0.00368)	(-0.00542)	(-0.00395)
Annual Avg. Rainfall	-0.00116**	-0.00145**	-0.00262***
	(-0.000467)	(-0.000714)	(-0.000578)
Elevation	0.000456	0.00103**	0.000446
	(-0.000338)	(-0.000476)	(-0.000367)
Hired Labor	0.567***	-0.442	-0.227
	(-0.171)	(-0.303)	(-0.231)
Adult Equivalents	0.039	-0.0719*	0.0124
	(-0.0273)	(-0.0386)	(-0.0301)
Extension Service	0.269***	0.0881	0.115
	(-0.0916)	(-0.158)	(-0.115)
Ln(Cassava Price)	-0.0318	-0.0038	-0.00581
	(-0.0242)	(-0.0437)	(-0.0306)
Ln(Beans Price)	-0.0433*	-0.0284	0.0645**
	(-0.0242)	(-0.0433)	(-0.0305)
Ln(Maize Price)	0.0582***	0.047	-0.00292
	(-0.0212)	(-0.0399)	(-0.0253)
Ln(Coffee Price)	0.0104	0.0117	-0.0192
	(-0.023)	(-0.0341)	(-0.0284)
2010 Dummy	0.158	0.159	0.419***
	(-0.112)	(-0.205)	(-0.152)
2011 Dummy	0.0961	0.376	0.764***
	(-0.147)	(-0.232)	(-0.184)
Constant	-0.493		12.22***
	(-0.907)		(-1.144)
Cutoff 1		-1.778	
		(-1.353)	
Cutoff 2		-1.472	
		(-1.343)	
Sigma			0.323***
			(-0.698)
% Correctly Classified	68.51%		
Observations	1,353	867	761

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

As a robustness check, table 6.4 below provides estimations for a parsimonious model of the triple hurdle where missing values have been calculated for their imputed means at the household-level. First, log-productive assets becomes a highly statistically significant determinant in the first stage decision in the parsimonious model, not being significant in the original. This provides useful information because ln(productive assets) was one of the variables with many missing values. Also, the coefficient for full time adult equivalents becomes statistically significant in the parsimonious model, along with district cassava price and district coffee, while not being in the first. However, district beans price loses statistical significance in the parsimonious estimations. Most of the coefficients stay relatively similar between the original and parsimonious model. As a method to check for robustness, most of the findings in the original model can be confirmed as consistent. For most of the interpretation, the original model will be used.

Table 6.4: Triple Hurdle Estimation (Parsimonious Model with Imputed Means)

Explanatory Variables	Stage 1: Production Decision	Stage 2: Market Participation	Stage 3: Net Sales
Ln(Land Size)	0.130**	0.377***	0.659***
	(-0.061)	(-0.119)	(-0.0939)
Head Sex	0.118	-0.139	0.342**
	(-0.0921)	(-0.129)	(-0.137)
Dist. % Rec Credit	-1.963***	-1.425*	-0.214
	(-0.58)	(-0.854)	(-0.775)
Ln(Productive Assets)	0.101***	0.129**	0.252***
	(-0.0365)	(-0.058)	(-0.053)
Head Education	1.83E-05	-0.0110***	0.00616*
	(-0.00219)	(-0.00293)	(-0.00349)
Urban	-0.343**	0.0219	-0.178
	(-0.144)	(-0.163)	(-0.203)
Dist. Pop. Center	-0.00369	0.0111*	-0.0109**
	(-0.00402)	(-0.00607)	(-0.00545)
Dist. Market	0.0148**	0.00588	0.0108
	(-0.00581)	(-0.0098)	(-0.00846)
Dist. Road	-0.00345	-0.00593	-0.00065
	(-0.0027)	(-0.0036)	(-0.00342)
Improved Seed	0.368***	0.306**	0.0721
	(-0.0954)	(-0.153)	(-0.111)
Head Age	0.004	-0.00139	-0.0131***
	(-0.00295)	(-0.00414)	(-0.00346)
Annual Avg. Rainfall	-0.000902***	-0.00110***	-0.00233***
	(-0.0003)	(-0.0004)	(-0.000374)

Elevation	0.000299	0.000713**	5.71E-06
	(-0.000217)	(-0.0003)	(-0.000313)
Hired Labor	0.541***	-0.353	-0.508**
	(-0.136)	(-0.267)	(-0.21)
Adult Equivalents	0.0371*	-0.0576*	0.0369
	(-0.0219)	(-0.0297)	(-0.0285)
Extension Service	0.129*	-0.0033	0.0471
	(-0.0692)	(-0.115)	(-0.102)
Ln(Cassava Price)	-0.0449**	0.0033	0.00412
	(-0.0198)	(-0.0322)	(-0.0279)
Ln(Beans Price)	-0.0252	-0.0325	0.0363
	(-0.0171)	(-0.0304)	(-0.0262)
Ln(Maize Price)	0.0421***	0.0152	-0.0128
	(-0.0152)	(-0.026)	(-0.0252)
Ln(Coffee Price)	0.0364**	0.0209	-0.0059
	(-0.0153)	(-0.0224)	(-0.021)
2010 Dummy	0.116	0.0209	0.175
	(-0.0816)	(-0.164)	(-0.117)
2011 Dummy	0.178*	0.102	0.483***
	(-0.0959)	(-0.157)	(-0.127)
Constant	-1.147*		12.72***
	(-0.696)		(-0.97)
Cutoff 1		-1.557	
		(-1.019)	
Cutoff 2		-1.18	
		(-1.017)	
Sigma			1.390443***
			(0.9319)
% Correctly Classified	63.83%		
Observations	2,480	1,495	1,290

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

In the original estimations from table 6.3, the results begin with the first stage decision of whether or not to produce HVA. Many of the theorized variables influencing agricultural household decisions – access to information, infrastructure, inputs, capital, and crop prices prove to be statistically significant factors in determining the probability of being a producer. Among the most important is household land size. Komarek (2010) states that in Uganda larger land size gives farmers greater capacity to allocate land to non-consumption crops without raising food security concerns. Land size increases are not only associated with greater probabilities of being a producer of HVA, but are also significant in determining whether a household is a net-selling market participant and conditional sales quantities. In this estimation, the coefficient for household land size supports such theories, further suggesting increasing household land size is conducive to commercial farming in Uganda.

Access to information by way of exposure to extension services is a significant factor influencing the production of HVA. Despite its noteworthy impact in stage one, its influence proves to have less of an effect in the subsequent stages in determining market participation outcomes and total net sales, conditional on being a net seller. This result proves to be consistent with the hypothesis and the available information that various policies in Uganda have sought to promote small-scale commercialization with extension services being a key tool to do so. The results show promising outcomes for Uganda's extension services and its positive effect on the probability of producing HVA. In Uganda, this has been flagged as an area of critical importance by various literature and national government.

In the parsimonious model, a significant relationship exists between the household's value of owned productive assets, a proxy representing household wealth, and the probability of producing HVA in all stages. Results indicate that not only do household asset positively influence HVA production, but are also associated with being net sellers in the market and greater margins of net sales. Endogeneity concerns are frequent when using this as an explanatory variable, therefore, results should be interpreted skeptically because this may not indicate causality. HVA production is widely cited to have high start-up costs and is capital intensive, therefore factors mitigating up-front costs and improve working capacity should, in theory, facilitate HVA adoption. Consistent with theory, is its positive relationship when predicting the margin of net sales, conditional on the producing household being a net seller. The dummy variable to indicate use of improved seed is a significant factor positively influencing HVA cultivation and being a net seller in stage two. These results are consistent with hypothesis that greater farm inputs will facilitate HVA production.

Households obtaining credit at the district level provides interesting results in its relationship with the first-stage decision to cultivate HVA. Results show farmers with greater shares of district-level credit availability are less likely to cultivate HVA with a relatively large magnitude. Immink and Alcaron (1993) stated low levels of credit availability have been identified as a key constraint to technology adoption entry to cash crop markets. However, the results obtained are mixed and inconsistent with expectations and prior theory. One possible explanation may be due to the low development of credit markets in Uganda and their access challenges, which has been cited on a variety of accounts[5].

Increasing age of the household head shows no relationship in the first two stages. However, its stage three outcome shows to be inconsistent with much of theory, showing a negative coefficient, indicating that of HVA net sellers, increasing age, a proxy for experience, is associated with declining net sales margins.

Gender of the household head shows interesting results; there is no significant relationship between HVA production and male and female heads. However, male heads are more likely to be net buyers in the market place if they produce HVA, whereas if the household is a net seller, conditional on being a producer, male heads are more likely to have a greater net sales margin than female heads. Years of education received from the household head shows no relationship in the first stage, although we find, conditional on being a producer, increasing years of education make the household more likely to be a net purchasing market participant. A possible explanation for this is that farming is a secondary profession of those with greater levels of education.

Full-time adult equivalents, (FTAE) which are an indicator of household labor availability, does not show a positively relationship with the probability of producing HVA, while producers of HVA are more likely to be net buyers as household's FTAE increase. These results in stage one are inconsistent with the notion that producers are more likely to cultivate HVA with greater working capacity. Hired labor, however, which is also a measure of labor availability is highly significant in influencing households to produce HVA. This may give indication that, households that can afford to purchase inputs, are more apt to commercialize.

Infrastructural characteristics provide mixed results. Counterintuitively, further distances to nearest market increase the probability of adopting HVA and the other infrastructure variables are not statistically significant. Consistent with theory, urban households are less likely to cultivate HVA. However, conditional on producing, increasing distances to the nearest road are associated with being a net buyer in the market. Findings for annual average rainfall are significant in all stages. In stage one, greater rainfall is associated with the

[5] Munyambonera, E., Mayanja, M. L., Nampeewo, D., & Adong, A. (2014). Access and use of credit in Uganda: Unlocking the dilemma of financing small holder farmers. Mpuga, P. (2010). Constraints in access to and demand for rural credit: Evidence from Uganda. *African Development Review*, *22*(1), 115-148.

likelihood of being not producing HVA. In stage two, households are more likely to be net purchasers with greater levels of rainfall and lead to lower levels of net sales in stage three – all which are inconsistent with the hypotheses.

Prices prove to be a significant determinant in the first stage decision to produce HVA. Maize, beans and cassava, predominantly consumption crops, are hypothesized substitutes for HVA products in Uganda. The price of beans appears to reduce the probability of cultivating HVA with exception of maize, which increases the probability of HVA cultivation. This outcome may be due to the fact many farmers will cultivate maize regardless of HVA cultivation. Cassava shows no relationship in the decision to cultivate HVA. Increases in the price of beans positively increase the net sales margin, conditional on the household producing HVA and being a net seller.

Average Partial Effects and Probabilistic Outcomes:

This research hypothesizes smallholders that cultivate HVA are more likely to be net sellers in the market. The probability of any given household being a producer of HVA is 39.3%. The predicted probability that any given household that produces HVA is a net seller is 90.6% with a standard deviation of 0.073 using 1,353 observations. Furthermore, the probability of any given HVA producer is a net buyer in the market is 5.6% *(SD = 0.051)*, while the probability they do not participate at all (autarkic) is 3.7% *(SD = 0.0022).* These calculations provide unequivocal evidence that smallholders who cultivate HVA are highly likely to orient themselves toward the market.

Burke et al. (2015) applies average partial effects (APE) to dichotomous explanatory variables that indicate the presence of various marketing channels. These calculations include the estimated partial effect on the probability of being a net selling producer, as well as the estimated partial effect of unconditional expected values of net sales, with respect to the presence of various dairy marketing channels. Given the wide range of HVA products in this analysis, no such explanatory variables were included in this analysis. Therefore, rather than use Burke's approach, the APE are applied to key explanatory variables to observe how they change unconditional expected values of net sales and the probability of being a net selling producer. The selected explanatory variables include those that have statistical significance and greater relevance to triple-hurdle study around HVA adoption and market participation. These include extension service contact, land holding size, distance to market, head age, urban versus rural households, use of improved seed, and productive assets. Standard errors[6] and the estimate's statistical significance levels are obtained by bootstrapping 100 replications. Table 6.5 provides this output of the estimated partial effect on unconditional expected values of net sales. Following table 6.5 will show the results for the APE on the probability of being a net selling producer across the selected explanatory variables.

Table 6.5: Estimated Partial Effect on the Unconditional Expected Value of Net Sales

Column (1) Explanatory Variables	Column(2) APE on Unconditional Expected Value of Net Sales (UGX)
$\frac{\partial(net\ sales\|\boldsymbol{x})}{\partial Ln(Household\ Land)}$	279,010.3**
	(123111.9)
$\frac{\partial(net\ sales\|\boldsymbol{x})}{\partial(Extension\ Service)}$	73,294.41
	(64654.28)
$\frac{\partial(net\ sales\|\boldsymbol{x})}{\partial(Distance\ to\ Market)}$	-6,257.88*
	(-5494.97)
$\frac{\partial(net\ sales\|\boldsymbol{x})}{\partial Ln(Productive\ Assets)}$	72,284.25
	(59663.02)
$\frac{\partial(net\ sales\|\boldsymbol{x})}{\partial(Head\ Age)}$	1731.14
	(5303.20)
$\frac{\partial(net\ sales\|\boldsymbol{x})}{\partial(Urban)}$	108,393.2
	(156594.5)
$\frac{\partial(net\ sales\|\boldsymbol{x})}{\partial(Improved\ Seed)}$	417214.5**
	(169415.9)

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

The results in table 6.5 are an important part of this study because these are the factors that will improve marketing opportunities for households that produce HVA. The results of the APE on the unconditional expected value of net sales provide indication that of HVA producing households, increases in landholdings, lower transfer costs, and use of improved seed increase the margin of net sales. A one standard deviation change in household land size is associated with a (UGX) 279,010.3 increase in expected net sales. Additionally, ability to

[6] Robust standard errors of the APE on the expected quantity of net sales and the probability of being a net selling producer of HVA are computed using statistical bootstrapping that relies on random sample replacement of 100 repetitions.

access local markets in terms of market distance supports theory. With every kilometer further away from the market that a household sits, one can expect a decrease of (UGX) 6,257.88 in market sales with an alpha level of 0.10. With respect to households that are exposed to extension services, the coefficient of the APE was not statistically significant, though the effect shows an average increase of approximately (UGX) 73,294.41. The APE for log productive assets are not statistically significant in explaining unconditional expected net sales. Uganda is densely populated and theory suggests that urban households have the potential to show negative returns to the market for a variety of reasons, however the APE for this variable is not statistically significant. HVA producing households that use improved seed are expected to have an average of 417,214.5 greater net sales in the market than those that do not. Following in table 16 shows the APE on the probability of being a net selling producer.

Table 6.6: Estimated Average Partial Effect on the Probability of being a Net Selling Producer of HVA

Column (1) **Explanatory Variables**	**Column(2)** **APE on Probability of being a Net Selling Producer**
$\frac{\partial Pr(Net\ Seller \mid \boldsymbol{x})}{\partial Ln(Household\ Land)}$	-.025
	(0.920)
$\frac{\partial Pr(Net\ Seller \mid \boldsymbol{x})}{\partial (Extension\ Service)}$	-.517
	(0.868)
$\frac{\partial Pr(Net\ Seller \mid \boldsymbol{x})}{\partial (Distance\ to\ Market)}$	-.005
	(0.784)
$\frac{\partial Pr(Net\ Seller \mid \boldsymbol{x})}{\partial Ln(Productive\ Assets)}$	-0.096
	(0.812)
$\frac{\partial Pr(Net\ Seller \mid \boldsymbol{x})}{\partial (Head\ Age)}$	-.008
	(0.861)
$\frac{\partial Pr(Net\ Seller \mid \boldsymbol{x})}{\partial (Urban)}$	1.130
	(0.764)
$\frac{\partial (net\ sales \mid \boldsymbol{x})}{\partial (Improved\ Seed)}$	-.527
	(0.901)

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

As opposed to the APE of the selected explanatory variables on the expected quantity of net sales, which appear intuitive and match theory, their APE on the probability of being a net-selling producer gives mixed results. Several of their signs do not match the expected signs put forward in table 4.1. Access to information via extension services, shows to have a negative probability of being a net seller if the household produces. Despite many of the coefficients here not being statistically significant, this can be seen as a valuable finding in itself. One conclusion that can be possibly be made is the variables that influence the market participation outcomes are different from those that influence a given household to cultivate HVA. This conclusion can be made based on the statistical significance found in many of the stage one results, whereas, their APE on the probability of being a net seller prove to be statistically insignificant.

Increased agricultural productivity via improving sales margins plays a key role in transforming rural agriculture. Shifting resources away from staple crops into HVA has proven to be one method to improve rural incomes. HVA producers are more likely to be net sellers in markets, demonstrating how smallholder crop diversification into higher valued products can lead to agricultural transformation.

The first hypothesis of this research can to a large degree be validated by observing the statistical significance of the variables that increase the probability of a household cultivating HVA in the stage one estimates. As stated, access to information, infrastructure, inputs, capital, and crop prices, are significant determinants of HVA cultivation. The parsimonious model shows that the value of household productive assets is a statistically significant determinant of cultivating HVA. This may information may indicate the importance of capital in the decision to cultivate HVA. Thus, if policy makers wish to better understand the dynamics driving smallholder adoption of higher valued crops, they must better understand these factors and their interplay to facilitate this process or make projections about cropping patterns.

It appears that, inherently, households who produce HVA are more likely to be net sellers in the market than they are to be autarkic or net buyers – based on estimated predicted probabilities. Which of the selected variables change the probability of a household being a net seller of the HVA producers, could not be explained through the APE with statistical significance – *inconsistent* with hypothesis. However, several of these same factors do determine market participation outcomes with statistical significance, though their precise probability cannot be inferred. It can be concluded from the triple hurdle model framework that households who produce HVA are more likely to be net sellers than not, but their specific probability lacks significance, although many of their signs match predictions with statistical significance. Thus, policies facilitating HVA adoption will likely result in a greater quantity of net selling smallholder farmers in the population.

6.3 Policy Recommendations

The findings of this research hold numerous policy implications designed for strategies that will promote agricultural transformation by creating a conducive environment and encouraging farmers to cultivate HVA which can lead to greater net sales margins. Suggestions will be made based on Uganda-specific literature and the findings of this study.

- **If governments wish to promote greater market opportunities for smallholder farmers in Uganda, policies should focus specifically on strategies to increase its uptake.** Those who make the decision to cultivate are not only likely to be more commercially oriented market participants, but also more likely to be net sellers rather than net purchasers in the market.
- **Creating an environment where smallholders have access to land allowing them to bring greater quantities of land under cultivation will promote HVA production and greater market sales**. Strengthening the security of land tenure and implementing a more flexible land market system are cited factors Uganda needs to focus on for smallholder land acquisitions and greater investments in HVA (Holden et al. 2014). From a food security perspective, there is broad agreement that the inclusion of HVA or non-food crops does not compete with crops produced for home consumption in Uganda (Komarek 2010).
- **To promote HVA production, improving the quality and capacity of extension services to facilitate technology transfers via technical training on HVA practices and marketing opportunities will be required**. Evidence shows that exposure to extension services and farming experience play an important role in HVA uptake decisions. However, Uganda has faced routine difficulties with agricultural extension services (FAO 2016).
- **Infrastructural improvements, specifically ones that facilitate market access, should be stressed**. Considering that the bulk of HVA sales are made in local village markets and the significance of market distance in increasing sales margins for HVA

producers, improving road quality of public infrastructure and strengthening the linkage between market channels and rural farmers needs to be carried out. Additionally, strategic investments in infrastructure specific areas, such as transport, support for farming organizations, agricultural extension facilities will integrate farmers better into supply chains and markets.

- **Capacitating less wealthy farmers with working capital and inputs will result in greater quantities of farmers producing HVA improved marketing opportunities, along with increased net sales for those who produce.** Increasing levels of wealth and inputs, such as improved seed and hired labor are associated with greater probabilities of HVA production and increased net sales margins. Evidence shows that capital and inputs are key factors to facilitate adoption and greater sales margins. The implications of this result, is that greater levels of working capital will assist in reaching HVA production objectives.
- **Capacitating women, relieving social barriers and improving their access to education are cited strategies to improve gender differences in farming outcomes (Farnworth, Akamandisa, and Hichaambwa 2011).** Differences in gender with respect to net sales among HVA producers warrant significant attention. Policies with this orientation will decrease gaps in marketing outcomes between male and female heads, specifically for HVA producers. Male headed households have approximately 27% greater net sales margins than female headed households that produce HVA.
- **Consistency with farm gate prices will decrease farmers expected risk when cultivating new crops, such as HVA, therefore policies to stabilize price are integral**. Uganda has been characterized as having large price fluctuations with constistently volatile markets (Komarek 2010). Ceteris paribus, prices influence Ugandan farmers' decisions to cultivate HVA.

Some research has speculated that policies that facilitate market participation of a set of products, such as HVA may also induce their cultivation. In Uganda, it is difficult to isolate which factors contribute to both. However, those who do cultivate HVA are more likely to have improved marketing outcomes, thus policies that focus on its uptake should be of focus.

CHAPTER 7: CONCLUSIONS

Theories of agricultural transformation posit that factor shifts from agriculture to non-agricultural sectors play an important role in economic growth and poverty reduction (Shilpi et al. 2016). Governments have attempted to devise strategies to identify what key factors catalyze these processes of structural transformation. This research argues that crop diversification can play an important role in this process. Therefore, advancing our understanding of the factors associated with decisions made by smallholder farmers around which crops to cultivate is critical to realizing these goals.

Historically, staple grains have dominated African agriculture due to food security needs, low levels of rural development, and subsidies that have promoted a narrow range of crops. Evidence is becoming abundantly clear that diversified products away from staple grains, needs to occur for greater growth in the agricultural sector. In Uganda, like many other sub-Saharan African countries, significant demand has emerged in regional, as well as international markets, for high value agricultural products. This is the result of increased incomes, urbanization and integrated markets. Yet, the share of high-value agriculture in total exports out of sub-Saharan Africa remains at a low level. A significant opportunity remains for sub-Saharan Africa, especially its smallholder farmers, to capitalize in supplying these global markets for high-value products. This research analyzes what factors can influence a smallholder farmers' decision to commence producing HVA and how that can lead to their different marketing outcomes and income generation.

Borrowing from Burke et al. (2015) this research uses a triple-hurdle model, which offers a new methodology that gives broader insights into market participation decisions and outcomes than before, involving an analysis of sequential decisions made by smallholder farmers. Such analyses are appropriate for less commonly produced crops, such as HVA or dairy.

The rationale behind using a triple-hurdle approach is to incorporate a third-stage involving the question to first cultivate HVA, which can have specific policy relevance. Prior models based on market participation use two-stage decision models, such as the double-hurdle, which allows researchers to formulate conclusions based on the selected factors associated with market participation along with its extent, in the second stage. However, policies oriented toward market participation may be underestimating the impacts they have on smallholder farming decisions. For example, policies that promote market participation for a particular product, may also be inducing non-producers of HVA to commence producing. Such policies can therefore have further reaching impacts than ones thought to only facilitate market participation. The triple hurdle model seeks to understand exactly this, could market participation strategies also be incentivizing smallholders to cultivate specific goods? These results can be used to guide policy that will encourage HVA cultivation.

Panel data from the World Bank's LSMS/UNHS surveys of Uganda is used for study in this research. While controlling for the factors that are hypothesized to influence crop diversity into higher valued products, triple hurdle results show that access to information, infrastructure, head education, rural households, inputs such as adult equivalents and improved seed use, capital, and crop prices, are significant determinants of HVA cultivation. A parsimonious model was also estimated using imputed means of variables that had missing values. In this estimation, the value of productive assets became highly statistically significant, which provides additional information pointing to the importance of capital in the decision to cultivate HVA. Additionally, results indicate that households that produce HVA are 90% more likely to be net sellers in the market than they are to be autarkic or net buyers – estimated based on the predicted probabilities. This could not be explained through isolating which factors contribute to greater *probabilities* of being a net selling household with average partial effects of the selected variables due to a lack of statistical significance. However, stage two estimates do suggest that household land size, head education, distance to market, hired labor and adult equivalents all play a significant role in determining a household's marketing outcomes, of HVA producers, be it net buyers, autarkic or net sellers.

Considering the array of initiatives carried out in Uganda to promote commercialization and crop diversification, extension services who can relay these national objectives to smallholder farmers are a key variable of study. Results provide valid indication that they are a strong driver of HVA cultivation with the largest magnitude on the probability of being a producer of HVA of all factors.

Infrastructure in Uganda has demonstrated to be a key area in need of policy focus. Public investments must be made in infrastructural facilities, particularly those that contribute to the ease of market access. Approximately 60-65% of smallholder HVA producers sell their produce in local village markets. Dually, the distance to nearest market and population center plays an important role in their market involvement and decision to cultivate. Therefore, focus on transport, support for farming organizations, agricultural extension facilities will integrate farmers better into supply chains and markets. Furthermore, gender, productive assets, land ownership and prices proved to be among the most important factors surrounding HVA marketing and its outcomes.

Considering the results and literature reviewed in this study, it is clear that improving smallholder marketing outcomes through greater incomes can be achieved by promoting HVA adoption. However, this is unlikely to be realized without effective policy implementation that creates an enabling environment for smallholder farmers to do so. Access to information, specifically through extension services that can transfer technology and knowledge around HVA, improved infrastructure that facilitates market access and lowers transaction costs, price stability, as well as input accessibility that improve working capacity, are all meaningful ways of working toward this objective. Most importantly, policy makers need to recognize that these factors are dynamic and do not exist or act in a closed system. Understanding their intersection and depth will help guide strategies for sustainable outcomes.

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