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Demand Analysis for Tomato, Onion, Peppers, and Fresh Okra in Nigeria

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To my brother

Yevgeniy Khaliukov (1978 - 1997),

my mother

Alla Khaliukova

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ABSTRACT

The results found in this study have implications for local Nigerian food producers, retailers, other participants of the food sector, and government food policy makers.

In this thesis the demand analysis for onion, peppers, fresh okra and tomato in Nigeria was conducted using General Household Survey data collected by the World Bank and the Nigeria National Bureau of Statistics. The two stage estimation procedure and Linear Approximation Almost Ideal Demand System addressing censoring were used to analyze the demand system. The analyses are based on the assumption that every household is maximizing its utility subject to a budget constraint. Standard errors on both stages of the estimation as well as for the calculated elasticities were adjusted using a bootstrap procedure.

Most of the demographic characteristics determining consumption were significant. Marshallian cross price elasticities suggest that the products are a mix of gross substitutes and complements, whereas positive values of Hicksian cross-price elasticities indicate that all vegetables are net substitutes. According to expenditure elasticities, not all of the vegetables appear to be normal goods. Negative expenditure elasticity for fresh okra indicates that the vegetable is an inferior good.

A combination of policies that increase purchasing power of population, and fosters food supply would benefit a developing country, like Nigeria, the most. Increased supply would trigger an increase in quantity demanded, improving the livelihood of agricultural producers, poor households and potentially creating more jobs in agricultural and related industries.

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ABREVIATIONS

AIDS	Almost Ideal Demand System
CDF	Cumulative density function
EA	Enumeration Area
FAO	Food and Agriculture Organization of The United Nations
FAOSTAT	The Statistics Division of the FAO
FBS	Food Balance Sheets
FDA	Federal Department of Agriculture
FV	Fruit and vegetable
GHS	The General Household Survey
GLS	The generalized least squares estimation
GHS-Panel	The panel component of the General Household Survey
Heckit	The Heckman's two-step estimation procedure
IAIDS	Inverse Almost Ideal Demand System
IFPRI	International Food Policy Research Institute
IMR	Inverse Mills Ratio
ITSUR	Iterated Seemingly Unrelated Regression
LA/AIDS	Linear approximation of Almost Ideal Demand System
LGA	Local Governmental Area
LSMS-ISA	Living Standards Measurement Study – Integrated Surveys on Agriculture
ML	Maximum Likelihood
N	Naira, Nigerian national currency
NBS	National Bureau of Statistics of Nigeria
PDF	Probability distribution function
QUAIDS	Quadratic Almost Ideal Demand System
Southern Asia	Afghanistan, Bangladesh, Bhutan, India, Islamic Republic of Iran, Maldives, Nepal, Pakistan, Sri Lanka
Sub-Saharan Africa	Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Swaziland, Togo, Uganda, United Republic of Tanzania, Zambia, Zimbabwe
UN	The Organization of United Nations
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
VIF	Variance Inflation Factor
West African countries	Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, St Helena, Senegal, Sierra Leone, and Togo
WHO	The World Health Organization

CHAPTER 1: INTRODUCTION

1.1. Problem Identification and Explanation

According to the Food and Agriculture Organization of the United Nations (FAO) "State of the Food Insecurity in the World" report (2012a), there were 868 million people who suffered from undernourishment in the 2010 - 2012 period. Approximately two billion people had negative health consequences caused by micronutrient deficiencies. Food demand analyses play a vital role in addressing the hunger issue. The distribution of the highest levels of hunger in the world has changed compared to the 1990 - 1992 period. Currently, Southern Asia has largest portion of the undernourished world population while the Sub-Saharan Africa region has improved (FAO, 2012b).

The sub-Saharan country of Nigeria is the focus of this thesis. Nigeria is rich in natural resources and agro-ecological diversity (Oladele et al., 2004). The country has fertile soil that has the potential to significantly contribute to global food security (Ariyo and Mortimore, 2011). Meanwhile, Nigeria is listed as the 54th poorest country in the world (UNDP, 2007). About 70.0% of population lives on less than US $1.25[1] a day (IFAD, 2012). Okojie et al. (2001) noted food deficits of 31.0% and 20.0% in 1980 and 2000, respectively.

Although 80.0% of the external earnings of Nigeria come from the oil sector, agriculture contributes about 38.0% to the GDP (Gross Domestic Product) (FDA, 2008). Approximately 70.0% of the Nigerian population is employed in the agricultural sector (FDA, 2008). Women and children in Nigeria account for about 75.0% of the total population with over 70.0% of them living in the rural areas (Maziya-Dixon et al., 2004). Women's share of food production in Africa is 80.0% (Huston, 1993), while in Nigeria about 70.0% of farm work is done by women (Mijindadi, 1993) and 60.0% - 80.0% of the agricultural work force is women (Bzugu and

[1] $1 = N161.5 at http://themoneyconverter.com/USD/NGN.aspx as on July 13, 2013.

Kwaghe, 1997). According to the FAO’s latest approximations (FAO, 2012b) women account for 35.0% - 45.0% of the agricultural labor force in Nigeria, Botswana, Ethiopia, Lesotho, Mali, and Morocco.

The predominant food items in the Nigerian diet are starchy staple foods (Okafor, 1983, 1995), particularly rice, gari and yam in the Edo, Delta and Lagos states (Ojogho and Alufohai, 2010). However, vegetables also play an important role serving as essential sources of proteins, vitamins, minerals, and amino acids (Okafor, 1983, 1995). As noted by Okafor (1983, 1995), the food consumption of the poor rural Nigerian population is heavily dependent on wild species with the majority of the vegetables harvested from the wild. Nigeria, among other West African countries, is experiencing social and economic changes which are associated with changes in food consumption patterns (Lopriore and Muehlhoff, 2003).

The population of Nigeria is growing rapidly. From 150 million in 2008, it increased to 166 million by 2012 (FAOSTAT, 2011), resulting in higher demand for food, agricultural land, livestock production, and fuel wood (Sanyal and Babu, 2010). The population has increased at a much higher rate than the growth in food supply increasing the gap between national food production and the local demand for food (Adeoye et al., 2011). During 2007 - 2009, the undernourished population of Nigeria was 11 million people or 7.0% of the total population (FAO, 2012b). During 2010 - 2012, the estimate of the undernourished population has increased to 14 million people or nearly 9.0% of the population (FAO, 2012c). Despite progress in the Sub-Saharan region of Africa, the number and the percentage of the undernourished population of Nigeria increased over the past years. Omonona (2008) states that although the incidence of poverty declined from 65.6% to 54.4% between 1996 and 2004, the actual number of poor people in Nigeria increased from 67 to 70 million during those years.

Undernourishment has multiple negative consequences. Pinstrup-Andersen (2006) notes that nutritional problems result in low labor productivity, reduced economic growth, poverty, and large demands for public funds. In studies from Sierra Leone, Strauss (1986) concluded that increased nutrient intake indeed raises farm labor productivity.

According to the World Health Organization (WHO) report "Levels & Trends in Child Mortality" (2012), 80.0% of the world's under-five deaths in 2011 occurred in only 25 countries, with 50.0% of them occurring in only five countries: India, Nigeria, Democratic Republic of the Congo, Pakistan and China. More than a third of under-five deaths worldwide belong to India (24.0%) and Nigeria (11.0%). In 2011, the children under five and the infant mortality rates in Nigeria were 124 and 78 per 1,000 live births, respectively (WHO, 2012). The average life expectancy for men and women is 52 and 54 years (WHO, 2011). Morbidity and mortality in children are primarily caused by protein-energy malnutrition and nutrient deficiency (Agary and Gillespie, 1993; Federal Government of Nigeria and UNICEF, 1994; Maziya-Dixon et al., 2004; NPC and ORC MACRO, 2004). Onimawo (2010) argued that half of the deaths in Nigeria are explained by malnutrition. There are two major types of malnutrition: overnutrition and undernutrition (Mendez et al., 2005). One of the extremes of malnutrition is being overweight[2] (De Onis and Blössner, 2003). Overweight prevalence in pre-school children was recorded by the national survey data in Côte d'Ivoire, Nigeria and Senegal (Lopriore and Muehlhoff, 2003). Afolabi et al. (2004) found a high risk of obesity among Nigerian urban market women. FAO (2004) claimed that in Colombia, Kyrgyzstan, Turkey and Nigeria rural overweight population exceeds urban overweight citizens. Using a community survey of underweight, obesity and overweight in two suburban communities in northern Nigeria, Bakari et al. (2007) found both

[2] The status of malnutrition is determined by Body Mass Index (BMI). BMI is calculated by dividing weight in kilograms by the square of the height in meters of the individual. BMI<18.5 means that person is underweight (Lopriore and Muehlhoff, 2003), 25<BMI<30—overweight, and BMI>30—obese (Maité et al., 2004).

over-nutrition and under-nutrition issues to be common in these communities.

Undernourished populations have a much lower resistance to disease. Malnutrition causes nutritional night blindness, nutritional edema, nutritional anemia, obesity, cardiovascular diseases, diabetes, certain cancers, and premature death (Gold et al., 1940; UNICEF, 2004; Pinstrup-Andersen, 2006). According to WHO (2003), deficiency in fruit and vegetable (FV) consumption caused 19.0% of gastrointestinal cancers, 31.0% of ischemic heart diseases and 11.0% of strokes globally in 2002. Sufficient consumption of FV could save up to 2.7 million lives annually (WHO, 2003). The empirical literature highlights the importance and favorable potential of FV consumption and its role in bringing about a reduction in the incidence of cancer, heart disease, diabetes, and obesity (van't Veer et al., 2000; WHO, 2003). Tohill (2005) raised the possibility of a positive impact of FV consumption on satiety and decrease in the feeling of hunger.

Fruits and vegetables are rich in bioactive compounds such as dietary fiber, vitamin C, carotenoids, and components like glucosinolates, folic acid and (iso)flavonoids that have beneficial health effects (van't Veer et al., 2000; Kris-Etherton et al., 2002). Lee et al. (2009) conducted a pooled analysis of 13 studies on the application of FV consumption to reduce the risk of renal cell cancer and concluded that the increase in FV consumption is indeed positively associated with the decrease in risk of renal cell cancer. New et al. (2000) suggested a positive relationship between FV consumption and bone health. The high intake of FV is associated with a modest reduction in risk of major chronic diseases (Hung et al., 2004; Pomerleau et al., 2005). The observed benefit is due to a lower risk of cardiovascular disease, not cancer noted by Hung et al. (2004) and Willett (2010).

Responding to the importance of FV consumption, this thesis estimates the demand

system for a group of vegetables consumed in Nigeria. The majority of academic studies in demand analysis use aggregated group of fruits and vegetables (Chern et al., 2002; Liu and Chern, 2003; Gockowski et al., 2003; Agbola, 2003; Yen et al., 2004). This thesis is focused on four widely consumed vegetables: tomato, peppers, onion and fresh okra as each of them has essential human health implications. Idah et al. (2007) noted that exactly those products are popularly transported in the country, which means that vegetables are commonly consumed and transported to further located markets. Poly-Mbah et al. (2010) showed that tomatoes and onions are among the food products that significantly contribute to the Nigerian consumer food price index and should be in focus of government programs that address food insecurity.

A large portion of the agricultural production system relies on small, two-hectare farm households that primarily produce food commodities for household consumption or local markets while relying on rainfall and not irrigation systems (Sanyal and Babu, 2010; IFAD, 2009; Adejobi and Babatunde, 2010). The other portion belongs to the improved irrigation system that consists of small-scale irrigation for agricultural production and large-scale commercial irrigation farming (AFDB, 2005). Despite its own large agricultural sector, Nigeria continues to increase its demand for foreign food products, especially from neighboring countries. The necessity of imported food commodities is partly explained by the rapid population growth, damaging agricultural production floods, and ethnic conflicts (FEWS NET, 2013; Jacob, 2012).

Nigerians frequently experience agricultural price volatility. Previously the fluctuation was mostly associated with the gap between planting and harvesting seasons and a poorly developed infrastructure among other reasons (IFAD, 2009). Poly-Mbah et al. (2010) listed the rise in transportation costs caused by bad roads and expensive fuel, farm gate price, and the lack

of proper storage among reasons for high cost of food products in Nigeria. The rise in transportation cost in Nigeria significantly affects the production of maize, yam and vegetables (Akande, 2003). Akande (2003) adds the export of food commodities to neighboring countries as another reason for high domestic prices.

The production of tomatoes in Nigeria has been gradually increasing, from 10 g per capita per day in 1985 to 25 g in 2009 (FAOSTAT, 2011). Tomato is considered to be an important dietary staple vegetable. Due to continuous demand for tomatoes in Nigeria, farmers have increased production, cultivating tomatoes “in and out of season” (Agele et al., 2002). The price for tomatoes has varied over the years. The recorded peak of the price per ton of tomatoes was almost five times greater in 1998 ($1,776.00) compared to the price in 1992 ($378.10). The prices stayed relatively stable during 2005 ($658.10) and 2008 ($790.60) years (FAOSTAT, 2013). As a perishable vegetable, tomato has frequent variations in price, even on daily basis (Adeoye et al., 2009). The peels and seeds of tomatoes have been found to be rich sources of phenolic compounds (George et al., 2004; Toor and Savage, 2005; Balasundram et al., 2006) that have multiple biological effects, including antioxidant activity (Kähkönen, 1999). Tomatoes are rich in nutrients, potassium, vitamin A, vitamin C and vitamin E, carotenoids and phytochemicals that may lower risk of cancer (Campbell et al., 2004). The consumption of tomato products were reported to reduce the risk of some cancers in works of Chan et al. (2005), Giovannucci et al. (2002), Giovannucci (1999), and Rao and Agarwal (1998).

The supply of onions has varied over the years. In 1960s it was 20 g per capita per day, 13 g in 1985, 21 g in 1994, and 12 g in 2009 (FAOSTAT, 2011). According to the FAO’s estimated data using trading partners database, in 2010 Nigeria exported 60 metric tonnes of dried onions that were worth US$17,000 (FAOSTAT, 2013). Organosulfur compounds in onions

have cardioprotective effects (Kris-Etherton et al., 2002). Research finds that onions possess essential antioxidant, anti-inflammatory, and antimicrobial properties (Choi et al., 2007). According to Galeone et al. (2006), such properties of onions may treat and prevent cardiovascular diseases, cancer, and others diseases. Gorinstein et al. (2008) found that even cooked onions were rich in bioactive compounds and the level of antioxidant activities did not decrease significantly.

Erinle (1989) noted that 40.0% of the total daily vegetable consumption in Nigeria was peppers, commonly used in culinary recipes and seasonings (Idowu-Agida et al., 2010). Grown everywhere in Nigeria, peppers often have very low yields as determined by low soil fertility, weeds and diseases (Adigun, 2001; Idowu-Agida et al., 2010). Production costs of peppers differ in dry and wet season, being higher in the dry season because of the irrigation needs (N268,699 per ha) compared to the wet season (N251,755 per ha) (Idowu-Agida et al., 2010).The importation of peppers has increased between 2000 and 2008, from 19 tonnes to 575 tonnes with the largest portion of imported peppers coming from Belize (FAOSTAT, 2013). In 2010 Nigeria imported 266 tonnes of peppers (FAOSTAT, 2013). Many studies have linked the consumption of food products that are rich in vitamin C with a reduced risk of cancer (Padayatty et al., 2003). Navarro et al. (2006) calls pepper fruit an important agricultural crop that contains vitamin C and is known as an excellent source of natural colors and antioxidant compounds (Howard et al., 2000; Lee et al., 1995). Those food compounds prevent widespread human diseases, including cancer and cardiovascular diseases (Sies, 1991).

Fresh okra is among most important vegetable crops cultivated in Nigeria (Tindall, 1983; Farinde et al., 2007). Okra is used to thicken soups and stews (Ihekoronye and Ngoddy, 1985), often sliced and sun-dried (Inyang and Ike, 1998), and stored frozen (Olorunda and Tung, 1977).

As okra is one of the vegetables that is not frequently imported, by the end of the dry season consumers experience significant supply shortages (Adeoye et al., 2013). Due to inefficient information flow, the communication of prices between urban and rural markets for okra is very slow (Adeoye et al., 2013). Prices tend to be higher in urban areas. Maximum and minimum market prices in the rural markets were N109.52 per kg in March 2007 and N32.24 per kg in August 2004 (Adeoye et al., 2013), whereas the maximum and minimum market prices in urban markets were N236.39 per kg in June 2005 and N32.88 per kg in August 2004 (Adeoye et al., 2013). Okra is rich in carbohydrates, proteins, and vitamin C (Adeboye and Oputa, 1996; Alimi, 2005). The essential amino acids found in okra are similar to those in soybeans (Farinde et al., 2007). An okra plant has variety of uses: it is a food source for people and feed for the cattle; it is also used in medicine as a blood volume expander (Farinde et al., 2007). The fresh okra plant is used as a food additive against some gastric diseases in Asian medicine (Lengsfeld et al., 2004). The plant is also used in paper production and the confectionery industry (Markose and Peter, 1990).

The other-vegetables-good includes eggplant, leaves of cocoyam and spinach, cassava, yam and cocoyam, white and yellow gari, potatoes and sweet potatoes, and other roots and tubers. It is not in the focus of this thesis and will be dropped from the demand system estimation (the more detailed explanation of this issue will be given in Chapter 3 and 4). However, it is important to note that Nigeria annually produces 14 million tonnes (approximately 25.0%) of the total cassava production of Sub-Saharan Africa region (Polson and Spencer, 1991), while 425 tonnes of cassava were imported to Nigeria in 2010 (FAOSTAT, 2013). Cassava roots are processed into gari (Onabolu et al., 2002). In Nigeria the demand of yam tubers always exceeds the yams' supply. Yam is consumed at different stages of processing, used as flour, the

component of snacks, and also as animal feed (Amusa et al., 2004). Nigeria annually produces 22 million tonnes (approximately 73.0%) of the world production of yams (FAO, 1998). The imported quantity of potatoes varies in Nigeria. The remarkable difference was between years 2007 and 2008 when the import increased from 27 to 178 tonnes, while the export of potatoes was 331 tonnes in 2007 and 794 tonnes in 2008 (FAOSTAT, 2013). The leaves of cocoyam, spinach and other leafy vegetables that are rich in flavor play a vital role in Nigerian diet, yet the supply of these leaves changes significantly between rainy and dry seasons (Mepba et al., 2007). Eggplant (garden egg) mostly grown in Southeast Nigeria has valuable nutritional leaves and fruits (Onunka et al., 2011). According to Onuoha (2005), Okafor (1993) and Maraizu (2007) eggplant is rich in minerals, vitamins, carbohydrate, and water substances that prevent a number of diseases.

The main target beneficiaries of the current demand research analysis are poor rural Nigerian families, who have overall higher rates of mortality and morbidity than the rest of the population (Bruinsma, 2003). The current state of hunger imposes significant economic costs on Nigerian society. The reduction of the level of malnutrition is an essential goal for national governments, civil society, NGOs, the international organizations, funding agencies, development projects, and the international community (Bruinsma, 2003; Pinstrup-Andersen, 2006). The demand analysis is also of benefit for local producers, the health care and confectionery industries, as well as local and international food policy decision makers. The increase of FV consumption has to be among the major foci of all participants of public health promotion (van’t Veer et al., 2000).

1.1.1. Research Objectives

The objectives of the thesis are: (1) to identify and evaluate the major demographic factors that influence the consumption behavior among rural and urban households for tomato, peppers, onion and fresh okra in Nigeria; (2) to estimate price and expenditure elasticities that will be valuable in local food production decisions, the development and revision of agricultural food policies and programs.

CHAPTER 2: LITERATURE REVIEW

2.1. Demand analysis

The volatility of world food prices motivates extensive food demand analyses. A set of literature exists concerning consumption behavior, the linkages between agricultural production and labor productivity, and the implications for improved nutrition and health status in developing countries. The researchers analyze demand using concepts of economics, agriculture, health, and nutrition (Alfonzo and Peterson, 2006; Hovhannisyan and Gould, 2011; Meenakshi and Ray, 1999; Zheng and Henneberry, 2009).

An increase in the consumption of FV is an essential public health issue (Rasmussen et al., 2006). Despite the recommendations and medical warnings of insufficient FV consumption, a large portion of the population, including those in most Western countries (Vereecken et al., 2004; Yngve et al., 2005), Asian countries (Lee et al., 2001; Musaiger and Gregory, 1992; Shi et al., 2005; Omidvar et al., 2003), Costa Rica (Monge-Rojas, 2001) and African countries (Peltzer and Pengpid, 2010; Ruel et al., 2005) consume much less FV than the recommended 400 g per person per day (equivalent to 146.00 kg per person per year) (WHO/FAO, 2003). The quantities recommended by WHO must be followed by recommendation on the FV mix as there is a difference in nutritional values among plantains, leafy vegetables, and tomatoes (Ganry, 2007). Cereals are the principal component of the diets of the poor in developing countries, with a much smaller part being provided by foods of animal origin, vegetables, and fruits (Faber et al., 2010). The average per capita daily quantities of fruits and vegetables consumed in South Africa are at least half those recommended by WHO/FAO (Rose et al., 2002). The FV consumption ranged from 26.70 kg to 114.00 kg per person per year in the Ethiopia, Burundi, Malawi, Mozambique, Tanzania, Rwanda, Kenya, Uganda, Ghana, and Guinea (Ruel et al., 2005). The poor FV

consumption is due to affordability, and, to some extent, availability as was explained by South African women in the KwaZulu-Natal and Western Cape provinces (Love et al., 2001). It is consistent with Banwat et al. (2012) who determined cost and seasonal availability to be two major factors that influence the FV consumption in Tudun Wada Community of Jos North Local Governmental Area (LGA), Central Nigeria. Poly-Mbah et al. (2010) in their study in Imo State, Nigeria stated that the price of the products play a major role in producers decision to supply and consumers choices to demand. The consumption of food products in Nigeria is determined by their availability in different agro-ecological zones; consequently the consumption of certain foods is higher in regions with better production of these products (Maziya-Dixon et al., 2004).

Kearney (2010) noted that changes in consumer behavior and nutritional diets are sensitive to culture, beliefs, and religious traditions. The commodity targeting programs might be efficient when products are associated with ethnic or religious groups (Cox et al., 1998). Stewart et al. (2004) and Casagrande et al. (2007) found differences in consumption and dietary patterns among different ethnicities. The Nigerian population consists of more than 250 ethnic groups (Maziya-Dixon et al., 2004). Jacob (2012) noted that over the last fifty years Nigeria has suffered as the result of ethnic divisions as well as constant political, economic, religious, and class conflicts. The author argued that all of the above mentioned conflicts cause numerous deaths, starvation of the local population, mayhem, and property destruction. Pinstrup-Andersen et al. (1999) and Pinstrup-Andersen (2000) noted that armed conflicts in African countries complicate the food insecurity situation and cause degradation of natural resources. The diversity in consumption behavior among ethnic groups could be of interest for further research and should be included in survey questionnaires, but was not considered in this research.

The empirical literature suggests that people living in urban and rural areas have different

diets (Popkin, 2001; Popkin and Du, 2003; Popkin and Ng, 2007). The diet of urban citizens is usually more diverse than the diet of rural populations (Ruel and Garrett, 2003; Smith, 2004; Regmi and Dyck, 2001). Significant differences among regions within different countries could be explained by FV availability and prices (Ruel et al., 2005). Bopape and Myers (2007) in their study in South Africa found demand behavior to differ significantly between rural and urban households. When the total household expenditure rises, the urban and high income households tend to be more responsive in their expenditure decisions for fruits and vegetables than rural and low income households (Bopape and Myers, 2007). However, the regional effects, difference between food consumption in northern and southern India were mixed and difficult to interpret, nevertheless the study revealed that regional differences in consumption patterns are present (Abdulai et al., 1999). The expenditure elasticities of fruits and vegetables in urban and rural India were less than one (Abdulai et al., 1999). The diversity in diets of rural and urban dwellers in Nigeria is expected.

Kennedy et al. (2004), in their study on the globalization of food systems in developing countries, evaluated Nigeria, the United Republic of Tanzania, South Africa, Bangladesh, China, India, the Philippines, Fiji, Brazil, Chile, and Colombia and found the Philippines, Nigeria and the United Republic of Tanzania to have the largest urbanization trends. Ojogho and Alufohai (2010) in their study in Edo, Delta and Lagos states of Nigeria found that the majority of the households were male-headed and located in urban centers. The diversity in diet between urban and rural sectors in Nigeria is expected.

The economic activities differ between Northern and Southern Nigeria, being lower in the Northern region (Akinleye, 2009). Although the production of FV is mostly concentrated in the southern Nigeria, the majority of the tomatoes, onions and peppers are grown in the north

(Idah et al., 2007; Oyeniran, 1988; Erinle, 1989). According to the national consumer survey of the Nigeria Federal Office of Statistics, the average national household total expenditure during 1996 and 1997 was N5,194, while the average household total expenditure in the northwest zone was N2,941 (Akinleye, 2009). Poverty is more evident in northern Nigeria with the larger proportion of undernourished children present (Akinleye, 2009). Akande et al. (2009) found that Nigerian urban population spends 42.0% of their total expenditures on food products when rural dwellers spend 68.0% of their budget on that category. The income distributed in Nigeria more unequally than in Ethiopia, Madagascar, India, Niger, the United States, and Sweden (Omonona, 2009).

In Nigeria vegetables are called "women's crop" because they are primarily produced and marketed by women (AFDB, 2005). Using Canadian Community Health Survey Pérez (2002) found that women consume FV more often than men do. Although the Nigerian agricultural sector heavily relies on women, the cultural norms, limited access to agricultural training, research and credit reduce women's opportunities to participate in agricultural production activities and consequently impact the levels of income between genders (Nkonya et al., 2008). Consistent with the pattern across much of Sub-Saharan Africa, in Nigeria the farming decisions and control over resources generally belong to men (Ajani, 2009). Southern Nigerian wives are expected not only to take care of children but also contribute to household income (Fapohunda and Todaro, 1988). The empirical literature provides evidence of the significant contributions of women to food production and processing in Nigeria (Afolami and Ajani, 1996; Ajani, 2001; Amaza et al., 1999; Ani, 2003). The difference in food expenditure share between male and female-headed households is uncertain. Empirical knowledge implies a positive relationship between women's income share and household expenditure share for food products

(Hoddinott and Haddad, 1995; Hopkins et al., 1994). A study in Central Nigeria found that females consumed more FV than males (Banwat et al., 2012). In seven out of ten countries the female-headed households spent more on consumption of FV than male-headed households (Ruel et al., 2005). However, Aromolaran (2004), who estimated calorie-income and calorie-women's income share elasticities for low income households from the rural areas of south western Nigeria, found that the calorie-income elasticity was positive and small, but four times as large as calorie-women's income share elasticity. Women's income share had small and negative effect on per capita calorie intake. The author rejected the hypotheses that increases in women's income share compare to men's share increased calorie intake. Aromolaran (2004) concluded that increasing female-income is not the best way to increase per capita calorie intake. Those results are consistent with Bouis and Haddad (1992) who reported calorie-income elasticity less than 0.2 when by common knowledge they were expected to be between 0.4 and 0.8. The income elasticities for FV ranged from 0.60 to 0.97 (Ruel et al., 2005). The negative response in increasing women's income to increase of calorie intake could be explained by female preferences for innutritious and expensive foods (Aromolaran, 2004).

Marital status might affect the household consumption behavior. In northern and middle zones of Nigeria the families in polygamous marriage experience poverty more often (Akande et al., 2009).

Physical inactivity was found to be associated with inadequate FV consumption (Pearson et al., 2009). Rasmussen et al. (2006) found a positive relationship between hours watching TV and insufficient consumption of FV. Peltzer and Pengpid (2012) in their study on FV consumption among in-school adolescents in five Southeast Asian countries, unlike the studies of Pérez (2002), Rasmussen et al. (2006), Vereecken et al. (2004), Neumark-Sztainer et

al. (1996), and Cartwright et al. (2003), did not find gender, age, smoking, drinking alcohol, mental distress to be associated with improper FV consumption. The men with diagnosed heart disease, high blood pressure, diabetes and cancer consumed FV more frequently (on average 4.6 times a day) than men without mentioned diseases (on average 3.9 times a day) (Pérez, 2002). Senior male and female population was found to consume more FV than the younger population (Pérez, 2002). The share of adult members of the household was positively related with the budget allocated for FV (Ruel et al., 2005).

Empirical research implies that a decrease in food prices will benefit poor consumers. However, Behrman et al. (1988) state that higher food prices will ultimately raise the incomes of some farmers in rural areas and possibly lead to improvements in nutritional consumption meaning higher food prices may also result in better nutritional consumption. Popkin and Ng (2007) studied changes in consumer consumption behavior due to changes in different food products prices. The authors concluded that the poor are more price responsive, the elasticity is larger and negative for fats and smaller and positive for carbohydrates and proteins. The change in food prices in Nigeria will have dissimilar effects on different households (Akande et al., 2009). Net producers would benefit from higher prices, while the poor households or net consumers would bear negative consequences (Akande et al., 2009).

Adejobi and Babatunde (2010) found total household expenditure, prices, and household demographic characteristics significantly influence the expenditure shares of food products. Omotesho et al. (2006), in the study of the rural farming households in Kwara State, Nigeria, found a negative relationship between family size and the household’s food security. The larger families were found to adjust their consumption behavior to relatively inexpensive commodities, and not expensive products (Abdulai et al., 1999). Rue et al. (2005) also found a negative

relationship between family size and FV consumption.

Empirical literature provides enough evidence to expect the demand for fruits and vegetables to be inelastic. Obayelu et al. (2009) found inelastic own price elasticities for FV. In their study in South Africa, Bopape and Myers (2007) estimated the uncompensated price elasticities for fruits and vegetables and found them to be price inelastic across all household groups. The own-price elasticities and total expenditure elasticities for traditional and processed vegetables were found to be high for most household types in study of Gustavsen and Rickertsen (2002). In study from China, Chern and Wang (1994) found that own-price elasticities for vegetables ranged from -0.42 to -0.59. Wu and Samue (1995) reported expenditure elasticities for vegetables of around 1.2, while Halbrendt's et al. (1994) estimate was 0.91. Wu and Samue (1995) showed the vegetable income elasticity of 0.45. You et al. (1996) found that with per capita increase in total expenditure the demand for fresh vegetables and most fresh fruits also increase, however no significant changes were found in consumption of individual fresh fruits or vegetables. Huq and Arshad (2010) estimated elasticities of demand for cereal, pulse, edible oil, vegetable, fish, meat, fruit, milk and spices in Bangladesh, the elasticities for vegetables and fruits were found to be 0.50 and 1.96, respectively. The estimated uncompensated own-price elasticity of demand for vegetables, and fruits indicated that if the price fell by 10.0%, the demand for these products would increase by 3.1% and 6.1%, respectively.

Food products are expected to be normal goods and own-price elastic. In the research from India, the food expenditure elasticities of all commodities were positive, the commodities were found to be normal goods (Abdulai et al., 1999). A similar result was found by Ruel et al. (2005). The concavity constraint from utility theory implies that uncompensated own-price demand elasticities should always be negative (Abdulai et al., 1999). Asano and Fiuza (2003)

found significantly negative own-price elasticities. In a study in South Africa, Agbola (2003) found fruits and vegetables to be necessities in the household diet. The empirical literature provides evidence that the level of per capita calorie intake has a strong positive but non-linear relationship with household income (Alderman, 1986; Bouis and Haddad, 1992; Subramanian and Deaton, 1996; Grimard, 1996). The household income has a positive effect on health in the works of Lundberg (1991), Ettner (1996), Deaton and Paxson (1998, 2001), Smith (1999), and Lindeboom et al. (2002). Idler and Benyamini (1997) suggested that additional purchasing power allows individuals to increase consumption, to purchase healthier food products and ultimately improve health status. Agbola (2003) concluded that with the income increase household expenditures for FV actually decreases. Several other studies reported that family size, dependency ratio, household income, and food expenditure were significant in explaining food security in different areas of Nigeria (Adesimi and Ladipo, 1979; Ma and Popkin, 1995; Falusi, 1997). Omonona and Agoi (2007) note that the socioeconomic characteristics, such as household size, per capita quantity consumed, age, level of education of the household head, and per capita quantity consumed of households positively affected the household food security level. Obayelu et al. (2009) concluded that household size, level of education, primary occupation, access to credit, and presence of children positively and significantly affected consumption of FV. Agbola (2003) concluded that race, age and gender of the household head, urbanization and size of the household affect demand for food products in South Africa. The age of the household head is not expected to be statistically significant, but level of education is expected to have an impact on consumer choices and personal expenses (Asano and Fiuza, 2003).

According to the Nigeria National Bureau of Statistics (NBS) children often do not attend school due to the perception of low quality education and the consideration of a weak

relationship between education and employment opportunities (Akande et al., 2009). Education was found to have a significant connection with the food consumption of relatively expensive food commodities (Abdulai et al., 1999). Educated household heads were found to have fewer children and higher expenditures for relatively expensive nutritious foods (Abdulai et al., 1999). In five out of ten countries households that have at least one person with secondary education allocated smaller budget shares to fruits and vegetables (Ruel et al., 2005). The author assumed that negative relationship could be related to the fact that more educated households tend to have working mothers and move from healthy FV consumption to precooked or processed foods. Akinleye (1998) concluded that street foods and fast foods in Nigeria contributed 50.0% to 90.0% of the total energy intake among 20 to 40 years old citizens.

Bruinsma (2003) claimed that the income growth itself is an efficient, but not sufficient, condition for eliminating hunger. The results of Behrman et al. (1988) who were using data from India and Bouis and Haddad (1992) who were using data from Philippine imply that the relationship between income and nutrient consumption is weak and income increase may not certainly be followed by increase in nutrient consumption among low-income families. Byerlee (2000) suggested that in case when the income elasticities are low and positive, relative benefits are largest for the poor, and when the elasticities are small and negative, absolute benefits will be greatest for the poor. Bouis (1996) noted that with income growth price elasticities of non-staple foods, which are usually taste-intensive, will decline. The income elasticities of demand for FV in poor countries were found to be 0.60 - 0.70, the price elasticities ranged from -0.35 to -0.50 (Ruel et al., 2005). Combined with education, own production of fruits and vegetables was called by the authors as a potential strategy to increase FV consumption in the household. The authors also suggested that consumer preferences play an important role in FV purchasing decisions.

Household surveys are excellent source of data on economic behavior (Deaton, 1997). The data used in the analysis is the General Household Survey (GHS) that was created during 2010-2011 by Nigeria National Bureau of Statistics (NBS) in cooperation with the Federal Ministry of Agriculture and Rural Development, the National Food Reserve Agency, the Bill and Melinda Gates Foundation, and the World Bank. There are different models that specify demand systems, the linear and quadratic expenditure systems, the Rotterdam model of Theil (1965, 1976) and Barten (1969), Translog model (Christensen et al., 1975; Jorgenson and Lau, 1975) and the model that remains popular during the past two decades (Bopape and Myers, 2007) the Almost Ideal Demand System (AIDS) of Deaton and Muellbauer (1980a). The AIDS model was used by Molina (1994) using Spanish data; Pierani and Rizzi (1991) using Italian data; Mergos and Donatos (1989) using Greek data; Chesher and Rees (1987), Burton and Young (1992) in the UK; in France Fulponi (1989); in Japan Hayes et al. (1990); Chen and Veeman (1991) using Canadian data; Blanciforti et al. (1986), Moschini and Meike (1989) using US data. The true AIDS model is known to be non-linear and difficult to estimate (Akinleye and Rahji, 2007), and many researchers choose to use a linear approximation of the Almost Ideal Demand System (LA/AIDS). Asche and Wessells (1997), Green and Alston (1991), Hahn (1994), Moschini (1995), Moschini et al. (1994), and Pashardes (1993) discussed in their works the relationship between AIDS and LA/AIDS. The difference between two systems is found to be in the form of the price index used. The two-step estimation is also widely used in demand analyses (Heien and Wessells, 1990; Perali and Chavas, 2000; Shonkwiler and Yen, 1999). The LA/AIDS with the Stone index has been used by Blanciforti and Green (1983), Chalfant et al. (1987), Gould et al. (1991), Moschini and Meilke (1989). Obayelu et al. (2009) used Quadratic Almost Ideal Demand System (QUAIDS) developed by Banks et al. (1997) to study the effect of socio-economic

characteristics on demand of food products. Bopape and Myers (2007) also used QUAIDS model to analyze food expenditure patterns among rural and urban households in South Africa, taking into consideration demographic characteristics, structural change, and seasonality effects. Eales and Unnevehr (1994) were followed by Grant et al. (2010) who also used Inverse Almost Ideal Demand System (IAIDS) in their demand analysis for North American fresh tomatoes. To derive and measure elasticities of different groups Yeong-Sheng et al. (2008) used the model where the estimator developed by Heien and Wessells (1990) is utilized to obtain the inverse Mills ratios (IMRs) via probit model. The IMRs are then included in the LA/AIDS model, also used by Edgerton (1996) in his research of food demand in Nordic countries, by Ojogho and Alufohai (2010) in their research in Edo, Delta and Lagos states of Nigeria, by Fulponi (1989) in her work from France, by Agbola (2003) in his work in South Africa and by many others (LaFrance, 2004; Erhabor and Ojogho, 2011; Akinleye, 2007). By using the procedures of Green and Alston (1990), the demand elasticities of the LA/AIDS models are computed at sample means. There is an opinion that the LA/AIDS model does not provide a direct estimate of income elasticity. Chern et al. (2003) and Chern (2000) suggested estimating the Engel function to derive income elasticity from expenditure elasticity (Yeong-Sheng et. al, 2008).

In this thesis the association between demographic household characteristics and demand for four vegetables in Nigeria will be analyzed using two-step censored estimation procedure and LA/AIDS model. The data used for the study is the General Household Survey, created by Nigeria NBS and the World Bank. The FAO Food Balance Sheets that contain combined data of Nigerian national official statistics estimated by NBS are also used in this thesis. The demographic factors that influence the consumption behavior of Nigerian households for tomatoes, peppers, onions and fresh okra will be evaluated using marginal effects. To derive and

measure expenditure elasticities, the Marshallian and Hicksian measures of direct and cross-price elasticities, the LA/AIDS model elasticities formulas will be used, addressing censoring.

CHAPTER 3: CONCEPTUAL FRAMEWORK

3.1 Utility maximization

The optimization problem is a popular approach in food demand system estimation. The problem could be written in two forms: (1) the utility maximization subject to the consumer's budget constraint or (2) an expenditure minimization for a given utility level. The problems are known to be identical under certain assumptions of utility maximization. One other approach is by means of indirect utility function, albeit it was claimed unsuitable in applications with non-negativity constraints (Wales and Woodland, 1983). Conventionally the consumption behavioral models are represented by the utility maximization problem subject to the consumer's budget constraint.

As an example of a single household, without incorporating the household demographic characteristics, the household makes consumption decisions to maximize utility subject to a fixed budget (*m*) constraint (Deaton and Muellbauer, 1980b):

$$max: U = U(q_1, \dots, q_n) \quad (1)$$

$$s.t.: \sum_{i=1}^{n} p_i q_i = m, \quad (2)$$

where i represents different kinds of commodities purchased by the household, so that q_i is the quantity consumed of the good i, p_i is the corresponding price of the good i, and *n* is the number of commodities consumed by the household.

To find utility-maximizing quantities demanded, apply the Lagrangian method:

(3) $L(q,\lambda) = U = U(q_1, \dots, q_n) + \lambda(m - \sum_{i=1}^{n} p_i q_i)$,

where the Lagrangian multiplier (λ) or the marginal utility of income equals $\frac{\partial U}{\partial m}$.

The fist-order conditions (FOCs) are obtained by setting the first partial derivatives of (3) with respect to q_i, and λ equal to zero:

(4) $\frac{\partial L}{\partial q_i} = U^{`} - \lambda p_i = 0,$ => $q^*(p,m)$

(5) $\frac{\partial L}{\partial \lambda} = m - \sum_{i=1}^{n} p_i q_i = 0$ => $\lambda^*(p,m)$

To reach maximum the ratio of the marginal utilities must equal to the ratio of the prices: $\frac{U^1}{U^2} = \frac{p^1}{p^2} = \dots = \frac{U^{n-1}}{U^n} = \frac{p^{n-1}}{p^n}$. Marginal utility divided by price must be the same for all commodities, $\frac{U^1}{p^1} = \dots = \frac{U^n}{p^n}$, the rate at which utility would increase if an additional dollar was spent on a particular commodity. If more satisfaction could be gained by spending an additional dollar on q_1 rather than q_2, the household would not be maximizing its utility. It could increase it by reallocating its budget.

The FOC is necessary but not sufficient condition in a constrained maximization problem. To ensure that a maximum is obtained, consider the Second Order Conditions (SOCs). SOCs require the relevant bordered Hessian determinant (symmetric matrix) or $H = \frac{\partial^2 L}{\partial (q,\lambda)^2}$ be positive, in a two good world the condition could be written as: $2f_{12}f_1f_2 - f_{11}f_2^2 - f_{22}f_1^2 > 0$, where f_{11} and f_{22} are the second direct partial derivatives of the

utility function, f_{12} and f_{21} are the second cross partial derivatives. The condition is satisfied when the function is strictly quasi-concave. It ensures that SOCs are satisfied at any point at which FOCs are satisfied and solutions are unique.

The optimal quantities consumed depend on budget (income) and prices. The demand function can be written now:

(6) $q_i^* = q_i(p_i, \ldots, p_n, m)$, i = 1,…, n.

There are several restrictions of economic theory that are imposed on the properties of the demand functions and have to be satisfied when modeling a demand system (Buse, 1994; Moschini, 1995; Yen et al., 2011). The restrictions are: separability, homogeneity, Slutsky symmetry and adding up conditions. However the empirical literature shows that these restrictions are frequently violated, for example in works of Browning and Meghir (1991), and Banks et al. (1997).

3.1.1. Separability

The concept of the separability assumption was introduced by Leontief (1947) and Sono (1961). The types of the sepability assumptions were studied by Byron (1970), Jorgenson and Lau (1975), Barnett (1979), and Barnett and Choi (1989). Winters (1984) and Alston et al. (1990) verified necessary, however not sufficient conditions for the direct weak separability (Moschini et al., 1994). Wolff (1985) noted that a separable utility function implies the decentralized approach to the consumer's maximization problem (Blackorby et al., 1978). The separability assumption in this thesis implies that consumption preferences of each household are separable and estimation does not require the presence of all kinds of goods purchased by the

household. Introduced by Pollak (1969, 1971), conditional demand functions for the certain goods that are written as functions of prices and total expenditures on these particular goods (Pollak and Wales, 1969) are used in demand system estimation. In other words, as explained by Gould et al. (1991) the household first decides how much it is willing to spend on tomatoes, peppers, onions, fresh okra, and other-vegetables and then, based on prices and demographic characteristics, it decides how to allocate budget among those products.

The direct utility function (1), where *U* is the household utility derived from the quantities of the consumed products, will exhibit weak separability as described by Pollak and Wales (1992) if there are *n* goods in *S* subsets, *S* functions $V^r(X_r)$ and a function *V*. *U* has the form:

$$(7) \qquad U(X) = V[V^1(X_1), V^2(X_2), \dots, V^s(X_s)]$$

where $s \geq 2$. Besides general sets (food, non-food, health expenditures), there are 16 food aggregates in the data used here (grains and flours; starchy roots; tubers and plantain; pulses, nuts and seeds; oil and fats; fruits; vegetables; products; meat; fish and sea food; milk and milk products; coffee, tea, cocoa and the like beverages; sugar, sweets and confectionary; other miscellaneous foods; non-alcoholic drinks; alcoholic drinks). Each group includes a number of products related to the group, for example soya beans, brown beans, white beans, groundnuts, other nuts, seeds and pulses belong to the "pulses, nuts and seeds" subgroup. X_r is the vector of goods in *r*th subset, for example "pulses, nuts and seeds", x_{ri} is the *i*th good in the *r*th subset, for example white beans, the number of goods in the *r*th subset is n_r. There are *n* subsets, because there are five different products that are included in "pulses, nuts and seeds" subgroup, so

$X_r = (x_{r1}, \dots, x_{rn_r})$ and $n_1 + n_2 + \dots + n_5 = n$.

When marginal rate of substitution (MRS)[3] of two goods from the same subset depends only on the goods in that subset, then the utility function exhibits weak separability (Pollak and Wales, 1992). For example, the MRS between tomatoes and onions does not depend on quantity consumed of canned tomatoes. This restriction is not as strong as, for example, a restriction of MRS between tomatoes and onions to be independent from quantity consumed of peppers (Heien and Pompelli, 1988).

In this thesis the utility of the household is derived from the consumption of onions, peppers, fresh okra, tomatoes and other-vegetables (that is, the combination of eggplant, leaves of cocoyam and spinach, cassava, yam and cocoyam, white and yellow gari, potatoes and sweet potatoes, and other roots and tubers) could be denoted as $U(q^{on}, q^{p}, q^{ok}, q^{t}, q^{oth})$ where the quantity demanded of onions is q^{on}, q^{p} is the quantity demanded of peppers, q^{ok} is the quantity demanded of fresh okra, q^{t} is the quantity demanded of tomatoes, and q^{oth} is the quantity demanded of other-vegetables.

The separability assumption suggests estimation of the two-stage (conditional) demand system (Moschini et al., 1994). A two-stage method was introduced by Heckman (1976) in his labor-supply model. Lee (1976) extended the method to a variety of models. Further changes in the two-stage model were suggested by Amemiya (1978, 1979).

3.1.2. Homogeneity

The homogeneity restriction is also called by economists “lack of money illusion” (Lewbel, 2001; Sulgham, 2006). It implies that the uncompensated (Marshallian) demand function is homogeneous of degree zero in prices and total expenditures. If all prices and total

[3] MRS is a maximum amount of a good that a consumer is willing to give up in order to obtain additional unit of another good.

expenditure (income) were proportionally changed by z, the quantity demanded and purchasing decisions of the household would not change. The restriction implies that if the prices of tomatoes, onions, peppers, fresh okra and other-vegetables were increased proportionally to the budget of the households by z%, the quantity demanded of each product would not change.

In the functional form, homogeneity of degree zero implies:

$f(z * p^{on}, z * p^{p}, z * p^{ok}, z * p^{t},\ z * p^{oth},\ z * m) = z^{0} f(p^{on}, p^{p}, p^{ok}, p^{t}, p^{oth}, m) =$ $f(p^{on}, p^{p}, p^{ok}, p^{t},\ p^{oth}, m)$, where $p^{on}, p^{p}, p^{ok}, p^{t}, p^{oth}$ are prices of onion, peppers, fresh okra, tomato, and other-vegetables, respectively.

The homogeneity restriction, for households, $k = 1, \dots, K$, where K = 3,033, is

(8) $$\sum_k p_k \frac{\partial q_i}{\partial p_k} + m \frac{\partial q_i}{\partial m} = 0,$$

When estimating the Rotterdam model Barten (1969) rejected homogeneity. In their demand analysis Christensen et al. (1975) rejected homogeneity when using a transcendental logarithmic utility function. Deaton and Muellbauer (1980a) also rejected homogeneity in their study. The authors assumed that the rejection of homogeneity is a symptom of misspecification. Ng (1995), Balcombe and Davis (1996), Attfield (1997), and Karagiannis et al. (2000) claimed that when using time series models with the appropriate time-series properties (unit-roots and cointegration), homogeneity and symmetry will not be rejected.

3.1.3. Slutsky symmetry

As noted by Lewbel (2001), the properties of homogeneity and Slutsky symmetry are the properties of the consumer rationality that are imposed during estimation of the demand function. The assumption of individual rationality is explained by the author as a failure to reject the

Generalized Axiom of Revealed Preference (GARP)[4]. The shortfall in representing the behavior of the households with more than one member by an individual consumer model is widely recognized (Lechene and Preston, 2000). The assumption of the representing preferences of several people in the household as preferences of a single individual was recognized earlier by Samuelson (1956). Symmetry is also described as a representation of consistency of consumer choices (Sulgham, 2006).

The Slutsky symmetry[5] implies the restrictions on the cross price partial derivatives of the Hicksian (compensated) demand functions, and not on finite first differences (Pollak and Wales, 1969).

(9) $$\frac{\partial h_k(u,p)}{\partial p_j} = \frac{\partial h_k(u,p)}{\partial p_k} \text{ for all } i \neq j$$

3.1.4. Adding up restriction

The adding up restriction implies that the estimated budget shares sum to one (unity), $\sum_i w_i = 1$.

The property could be written as:

(10) $$\sum_{i=1}^{n} p_i\, h_i(U,p) = \sum_{i=1}^{n} p_i f_i\,(p,m)$$

The sum of the estimated expenditure shares (w_i) of different goods (i) equals the households's

[4] " GARP**:** If an allocation X is revealed preferred to Y, then Y is never strictly directly revealed preferred to X, that is, X is never strictly within the budget set when Y is chosen" (Andreoni and Miller, 2002).

[5] The Slutsky symmetry could be proven by applying Shephard's lemma (1953) and Young's theorem.

total expenditure on these goods in shares form. So the last expenditure share is completely determined by the rest of the shares. There are 5 budget shares in total in this thesis. The restriction is:

$$(11) \qquad \sum_i p_i \frac{\partial q_i}{\partial m} = 1$$

It implies that the marginal propensity to consume should sum to one. So the quantity demanded is a function of the product of its own price and the function that depends on all prices and expenditure (Pollak and Wales, 1992). The adding up restriction implies restriction on the demand function and on the error covariance matrix (Pudney, 1989). To address the fact that join density function of the error terms is singular, one equation should be dropped from demand system estimation (Kasteridis et al., 2011). Unfortunately, under certain conditions the parametric restrictions do not always satisfy the adding-up restriction (Yen et al., 2003).

3.2. Empirical specification

There are two ways to account for demographic variables in demand analysis: estimate demand for the households with very similar or with diverse demographic characteristics (Pollak and Wales, 1992). In this thesis the second approach is used. The household demographic characteristics are used based on the empirical evidence that household size, education, age and composition of the household are often significant determinants of household consumption behavior. The studies of demographic effects could be found in works of Barten (1964), Parks and Barten (1973), Lau et al. (1978), Muellbauer (1977), and Pollak and Wales (1978, 1980).

The demographic information is represented by a vector (c) and includes gender,

education, age, marital status of the household head and other household's characteristics. It was assumed that the household faces a choice to consume tomatoes, onions, fresh okra, peppers, and other-vegetables only. The empirical model is derived by extending the discrete random utility theory (Pudney, 1989). Pudney discussed empirical models that treat non-consumption as an economic decision, when the choice of consuming the product strictly depends on the product's price. However there are personal preferences and tastes that certainly have an influence on households' consumption. Pudney noted that zero expenditure may be best modeled by means of a discrete shift in a variable altering the nature of individual preferences. The assumption of perfect markets for all goods implies that the household has a uniform utility from the consumption of own-produced and purchased goods (Taylor and Adelman, 2003), no separation between households' tastes and preferences were made. The income from the household members is assumed to be shared equally (Taylor and Adelman, 2003), albeit McElroy and Horney (1981) and Schultz (1990) have already questioned that assumption.

The household utility function (1) becomes $U(q, c)$ subject to the budget constraint (2). Optimal quantities consumed are expressed now as a function of prices, budget and household characteristics

$$q^* = f\,(p, m, c) \qquad (12)$$

It is assumed that the utility function (1) is continuous, increasing, and quasiconcave in quantities. The demographic characteristics included to the demand function do not alter these fundamental properties of the utility function (Yen et al., 2011).

CHAPTER 4: METHODS AND PROCEDURES

4.1. Data

Household survey data is used to detect the effects of price and income (expenditures) on the quantities demanded of different products (Deaton, 1997). The data used in this study was the first wave of the panel component (GHS-Panel) of the revised GHS that was collected by Nigeria NBS during 2010-2011. The instructions in accessing the data are found in Appendix A. The GHS survey is a part of a regional project, the Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA), in Sub-Saharan Africa that covers Nigeria, Ethiopia, Uganda, Tanzania, Malawi, Niger, and Mali. Nigeria NBS annually fields the cross-sectional GHS that questions approximately 22,000 households. The panel component was created by NBS in cooperation with the Federal Ministry of Agriculture and Rural Development, the National Food Reserve Agency, the Bill and Melinda Gates Foundation, and the World Bank. A sample size of 5,000 households was used in the GHS-Panel component. The survey was taken during post-planting (August - October 2010) and post-harvest (February - April 2011) visits to each of the households in the 36 states and the Federal Capital Territory, Abuja, federation of Nigeria. There were three questionnaires used in the survey: the Household Questionnaire (provides information on household demographic characteristics), the Agricultural Questionnaire (households' agricultural activities) and the Community Questionnaire (the socio-economic characteristics of the EAs). Although the sample is appropriate to represent the national and regional (urban and rural) levels, it is not applicable for state-level representation (NBS, 2012). More information on sample design is in Appendix B.

Another source of data used in the analysis is FAO Food Balance Sheets (FBS) that contain combined data of Nigerian national official statistics estimated by NBS. Although the

information is primarily gathered from farmer stock surveys, FAO (2001) emphasizes the fact that data is usually collected from different sources, which leads to missing information, time lags and sometimes inconsistency.

4.1.1. Data cleaning and modification

The primary cleaning process was done during the survey collection by re-visiting the households. Once the head office of NBS received the data, it was evaluated for out of range values and missing values once again. When the problems were identified, to avoid imputations, the problem descriptions were sent to the states that kept the survey questionnaires and if needed the households were re-visited again. There were a number of complications found during the survey work: pre-filled questionnaires resulted in mismatch between post-planting and post-harvest visits, the geographic codes that are used in the states and headquarters for LGAs and EAs were found to be not identical, not constant availability of electricity and internet, flooded roads, delays and misunderstanding between states and NBS head office (NBS, 2012).

Even though the data was previously cleaned, it was further modified to fit the analysis in this thesis. The data cleaning, the detection and evaluation of outliers are cumbersome but important processes. A lot of research has been done on statistical outlier detection techniques (Hawkins et al., 1984; Davies and Gather, 1993; Langford and Lewis, 1998). Hodge and Austin (2004) conducted a survey of these methodologies. The authors noted that outliers could be generated by all kinds of reasons: human error, instrument error, changes in behavior of systems or faults in systems. Osborne and Overbay (2004) wrote about a number of debates in the literature regarding actions, techniques, and methodologies that should be applied in the cases of extreme values that influence the analysis. In their paper the researchers summarized the various potential causes of the outliers, such as data recording or entry errors, motivated cautious

misreporting, and sampling errors.

The sample statistics analysis revealed a number of outliers and inconsistencies. It was especially hard to justify the origin of the obvious outliers because access to the actual questionnaires was not possible. Unfortunately, there were no means to check whether the values were recorded incorrectly; for example in quantities consumed or in the measurement unit codes, the complete list of units is presented in Table 1. To simplify the data analysis all unit measures were converted to kilograms or liters in cases of liquid commodities. The inconsistency among food commodities and recorded units in consumed, produced, purchased, and quantities received as a gift was eliminated by assigning certain unit codes to the corresponding commodities (see Table 2). For example, there were cases where units of bunch of plantains were used in measurement the goods from the grain and flour commodity group. There were cases where the values of consumption were positive, however there was no information on unit codes, it was considered inappropriate to make assumptions whether the unit should be in grams or small basin, or any other measurement unit.

All quantities in the data were recorded in several categories: consumed, purchased, grown, and received as a gift by a household during past seven days. To derive per capita quantities for each category, the total quantities for every product were divided by the number of household members. The information of the number of household members was retrieved from the annual household data set of the post-harvest visit. The extremely small values of consumed quantities could be explained by the fact that the product is not consumed by every member of the household but, for example, only by children under five years old. It is more complicated to explain large outliers.

In cases when the household reported consumption but all the values for other quantities

were zero, one would assume that it could be a good in storage. However the original data does not include a variable that indicates quantities of goods stored from previous activities. The observations with recorded missing values for all types of quantities and for all types of unit codes were dropped from the analysis at this stage. No imputations were made in those cases.

In present analysis the prices were derived by dividing household expenditure for the good by its total quantity purchased. Similar to Yen et al. (2003), in cases where the prices were not available, the enumeration area (EA) mean price computed on base of consuming households was imputed, if the prices were not recorded within EA, the next larger geographic area was used — local governmental area, state, zone, and national mean price. It was assumed that even if the household did not purchase the product during past week, it still faces the market prices.

The observations with missing values in consumption and expenditures were eliminated from analysis. The cases with missing values in unit codes for all quantities were also eliminated. If the quantity purchased was zero, but the amount spent was missing, it was set to zero, as if nothing was purchased then nothing was spent. According to the GHS-Panel Basic Information document the quantity consumed is the sum of purchased, grown, and gift food. Therefore the quantity consumed was set to the sum of known components. That helped to derive missing information from the available. For example if quantity consumed was equal to the quantity purchased or grown, or their sum but the value of the quantity received as a gift was missing, then it was recorded as zero. In cases where the quantity purchased was recorded as greater than zero but the amount spent was equal to zero, it was set to a missing value because there was evidence that the household had expenses on purchased food but did not record how much. When the amount spent was greater than zero, but quantity purchased was zero then the later was changed to missing value because the household had expenditures on certain products,

but the quantity purchased was not recorded. In cases of households with known expenditures but missing quantities, the quantities were later derived using market prices.

If total expenditure was missing and all the quantities were missing then the observation was dropped from the analysis. Households did not always report zero consumption; quantities were mostly reported for the consumed products. The households that have no information recorded for the product *i* were assumed to consume zero kg of that product *i*.

When the age of the household members were recorded incorrectly then the variable that reflected the correct age was used.

The demographic characteristics that were added to the consumption data is a combination of several tables from both post-harvest and post-planting visits. To choose from which of the visits to use the table, the number of missing values were compared and the more complete data set was selected. For example, the variable “sector of primary activity” (agriculture, manufacture etc.) had 584 missing values in post-harvest data, whereas the post-planting data set had only 387 observations missing. The post-planting data set was favored in this case.

The major part of the final data set is the food expenditure table of the post-harvest household questionnaire, section 10b. To see the patterns in consumption behavior within geographical zones, rural and urban areas, the geographic location variables were added from the post-harvest household questionnaire, section A (see Table 7).

The assumption that the outliers were caused by typing errors of certain interviewers’ in particular geographic area was rejected. In that case the outliers would be heavily present in different products in one particular zone, North-East, for example. However Figure 1 shows that the outliers were observed in different products as well as in different geographic zones.

Table 3 represents the calorie equivalence of the matched commonly consumed food products in Nigeria according to FAO FBS and data used in this study. The products that were not matched between the two data sets were assigned to the categories other or total aggregated calorie groups. Kilocalorie (kcal) equivalent for a kilo of white or yellow gari (1,600) was retrieved from the social fitness website "Fit Click". The weekly food supply in the Table 3 was calculated by multiplying daily supply by seven days in a week. FAO Total kcal daily consumption (2,711) was multiplied by seven to derive FAO weekly national kcal consumption ($FAOenergy = 2{,}711 * 7 = 18{,}977$). The meat, fish, milk and other animal products were not used in calculations as according to FAOSTAT FBS (2009) they correspond to a very small percentage of the average national diet (3.6%).

Similarly to the study "Determinants of Daily Food Calorie Intake among Rural and Low-Income Urban Households in Nigeria" conducted by Iyangbe and Orewa (2009b) the next formula was used to estimate the per capita kcal weekly consumption:

$$(13) \qquad TotalEnergy_{ind} = \sum_{ind=1} Q_{indi} B_i$$

where $TotalEnergy$ is a weekly per capita kilocalorie consumption of the twenty three commodities indicated in Table 3, Cereals - Excluding Beer + (Total) was not included as a general total category for cereals to avoid an overlap among the items, the Groundnut Oil and Palm Oil were also excluded from the equation avoiding overlap with vegetable oil+total category. Gari belongs to the starchy roots category that was found by Iyangbe and Orewa (2009b) to be 59.6 kcal per capita per day for both sexes. Consequently, the weekly consumption of gari can be calculated as: $Energy_{gari} = 59.6 * 7 \approx 417$; Q is the quantity in kilograms of the

weekly consumption of commodity *i* by individual *ind*; *B* is the food energy content in kcal of the commodity *i* that was retrieved using FAOSTAT FBS (2009) and "Fit Click" web site.

$$\begin{aligned}\text{TotalEnergy} = {} & 1{,}071(\text{Wheat flour}) + 14(\text{Other grains and flour}) + 1{,}491(\text{Rice}) \\ & + 1{,}792(\text{Maize}) + 1{,}953(\text{Millet}) + 2{,}065(\text{Guinea corn/sorghum}) \\ & + 1{,}582(\text{Cassava roots}) + 49(\text{Potatoes}) + 231(\text{Sweet Potatoes}) \\ & + 1{,}722(\text{Yam roots}) + 189(\text{Cocoyam, other roots and tubers}) \\ & + 714(\text{Confectionary}) + 567(\text{Other nuts, seeds }\&\ pulses) + 210(\text{Beans}) \\ & + 245(\text{Groundnuts}) + 2{,}548(\text{Butter, oil }\&\ fat) + 35(Tomatoes) \\ & + 28(Onions) + 196(Other\ vegetables) + 322(Plantains\ \&\ bananas) \\ & + 28(Pineapples) + 119(Other\ fruits) + 417(Gari) = 17{,}171\end{aligned}$$

(14) $$Bundle = \frac{\text{Totalenergy}}{\text{FAOenergy}} * 100\% = \frac{17{,}588}{18{,}977} * 100\% = 93.0\%$$

The bundle of chosen products ($Bundle$) corresponded to 93.0% of the average Nigerian diet estimated by FAO FBS. According to Iyangbe and Orewa (2009a, 2009b) the per capita daily calorie intake in Ikpoba-okha and Orhionmwon LGAs ranged from 996.22 kcal to 5,141.39 kcal. Those values are lower and higher respectively than FAO (2007) estimates of 1,760 kcal for Central Africa and 2,825 kcal for Southern Africa, and the estimates of 2,245 kcal for Eastern Africa and 2,618 kcal for Southern Africa found by van Wesenbeeck et al. (2009). Woodruff (2000) noted 2,420 kcal as the highest daily energy consumption by any age group in emigrant populations. Ogechi et al. (2007) in "Nutritional Status and Energy Intake of Adolescents in Umuahia Urban, Nigeria" study found that daily energy intake for males was 2,683.12 ± 113.91,

slightly lower for females, 2,333.60 ± 94.57. According to Ibrahim et al. (2009) the average national per capital daily calorie intake in Nigeria increased from 2,050 kcal in 1979 - 1981 to 2,430 kcal in 1989 - 1991 and to 2,700 kcal in 2000 - 2002 (FAO, 2004). In this thesis the lowest and highest found values recorded in empirical literature were selected. The next formulas were employed:

$$(15) \qquad bottom\ limit = 93\% * (kcal_{min} * days_{week})$$

$$(16) \qquad top\ limit = 93\% * (kcal_{max} * days_{week}),$$

so that from (15) the $\text{bottom limit} = 0.93 * 996.22 * 7 = 6{,}485.392$ or roughly 6,000 kcal per capita per week and from (16) the $\text{top limit} = 0.93 * 5{,}141.39 * 7 = 33{,}470.45$ or roughly 40,000 kcal per capita per week. Setting the range of per capita weekly calorie intake the sample is reduced from 4,851 to 3,448 households, which is 71.1% of initial sample. However in analysis were used 3,033 households (≈ 63.0%) that have complete information in all demographic variables. The distribution of the households by geographic variables can be found in Table 8. After keeping the households in a reasonable kcal consumption range, the per capita weekly consumption of over 10.00 kg of vegetables was detected. The values of above 10.00 kg were substituted by geographic area means. The top 3.0% of the price values were substitute by the price means in accordance with their availability in geographic areas.

There are different components of social wellbeing that includes possession of resources or durable goods (radio, car, etc.) (Morris et al., 2000). Following Arias and De Vos (1996) who used housing items to indicate socioeconomic status in different countries of Latin America, the

comparative scale was developed for material used in walls, floor and roof constructions, type of sewerage, property and type of cooking fuel, number of rooms in the dwelling, source of drinking water, and the availability of electricity, radio, tv, cell phone, computer, and internet, see Table 4. The scores were assigned depending on the quality or durability of the material used. The highest scores were assigned to the best quality materials and zero values indicated the materials of the worst quality. As for the availability of electricity and other items only two scores were used, unity if a household possesses for example radio and zero otherwise. The scores in rooms category were assigned according to the distribution of the values, bottom 25th percentile of the households have one or two rooms, 50th percentile of the values is at the households with three rooms, 75th percentile have four or five rooms, the households with more than five rooms got the highest score. As noted by Arias and De Vos (1996) the scores were assigned arbitrary. For example the category roof has three scores, “0” if the roof is made of grass, iron sheets, or other material, “1” if it is made of plastic sheeting, asbestos sheets and “2” if the roof is made of clay tiles, or concrete, the unit difference between iron sheets and asbestos sheets is not the same as difference between asbestos sheets and clay tiles. In other words the created variables are neither nominal nor interval. The scores were normalized according to the number of scores within a category in a following way:

(17) $$Sc_{cat}^{norm} = \left(\frac{sc_{cat}}{n_{cat}}\right) * 100,$$

where Sc_{cat}^{norm} is a normalized score of category *cat*; *cat* – 1, 2, …, 14 equivalent to the categories: walls, floor, roof etc. (see Table 4); sc_i is raw, not yet normalized score of the category *cat*; n_{cat} is the number of different scores within the category.

The scores of fourteen variables mentioned above were combined into the wellbeing index ($I_{wellbeing}$). As described by Silici (2010) and also used by McNair (2013) the index is a proxy of the wealth or wellbeing of the households, while ignoring the earnings and economic resources of the household.

(18) $$I_{wellbeing} = \sqrt[\alpha]{\frac{1}{n}\sum_{cat=1}^{n}(Sc_{cat}^{norm})^2}$$

In their study of the estimates of the household wealth in rural Africa, Morris et al. (2000) noted that information on total income could not be reliable and therefore not included in the index.
In (18) *n* is the number of variables included in the index formation. The index ranges from 0 to 100 and was calculated for each household.
For example: Calculating the index for the household with household id 10001 (see Tables 4, 5, and 6)

$$I_{wellbeing} of\ household\ 10001 =$$

$$\sqrt{\frac{100^2+100^2+0^2+100^2+100^2+100^2+100^2+66.67^2+100^2+100^2+100^2+100^2+100^2+100^2}{14}} = 94.28$$

4.2. Sample selection bias. Two-stage estimation procedure

A common problem encountered in demand analysis that uses cross-sectional micro data are recorded zero consumption values. Zero consumption might have several explanatory factors (Gustavsen and Rickertsen, 2002). In addition to the imputation errors, the household might never consume the products (tomatoes, peppers, onions, fresh okra or other-vegetables) due to health conditions (allergies), tastes and preferences, it might also not consume them during the

past seven days prior the interview or does not consume due to financial, budget restrictions. We focus on works of Greene (1981) and Heckman (1976, 1978, 1979) who developed methods for identifying and adjusting the selection bias in economic models. The matter of selection bias due to unobservable data was first comprehensively addressed by Lee (1978) and Heckman (1979). Amemiya (1985) noted that ignored zero observations in models of limited dependent variables may result in inconsistent parameter estimates. When only positive responses are used in demand analysis, ordinary least squares (OLS) regression produces inconsistent estimates of coefficients (Chern et al., 2002). Zero observations are sometimes substituted by the mean values computed from the positive responses (Gilley and Leone, 1991), but this approach produces biased results.

The Heckman's two-step estimation (Heckit) procedure (Heckman, 1978) is widely used in estimation of biased sample selection models (Winship and Mare, 1992; Nawata, 1993). The alternative approach could be full information maximum likelihood (FIML) estimation or approximated multivariate likelihood function with the sequence of bivariate specification (quasi-maximum likelihood procedure (QML)) that was applied by Yen et al. (2003), Yen and Lin (2002), and Harris and Shonkwiler (1997). Although the FIML procedure under certain assumptions produces efficient estimators and asymptotically correct estimates of standard errors, it is not widely used mainly because of its computational complexity (Murphy and Topel, 1985). The QML had not been well studied and applied in censored demand estimation besides in studies mentioned above (Yen et al., 2003). The two-step estimation was chosen for this thesis.

The first stage of Heckit procedure is the binary treatment choice. The second step is the linear outcome regression that depends on observable and unobservable factors including a bias correction term, inverse mills ratio (IMR) (Vella, 1998). The IMR plays the role of the

instrument that integrates the censoring unobservable variables (Heien and Wessells, 1990). As formed from the first stage, the standard errors of all coefficients have to be adjusted for sampling errors (Greene, 1981; Maddala, 1983). The IMR coefficient will indicate there is selection bias if it is statistically significant.

At least one of the explanatory variables used in the first stage should not be included in the second stage for identification (Maddala, 1983; Amemiya, 1985; Johnston and DiNardo, 1997), the variable that affects selection decision, but not the outcome (Sartori, 2003). Prices were not included in the first stage of estimating the probit models.

Total expenditure is determined jointly with the expenditure shares of the individual commodities (Eales and Unnevehr, 1988), making it endogenous in the expenditure share equations. If the expenditure is correlated with the equation errors, the estimators will be biased and inconsistent (Attfield, 1985). Estimation ignoring expenditure endogeneity may lead to inconsistent demand estimates (Bopape and Myers, 2007).

The two-step procedure, suggested by Heien and Wessells (1990), has been applied by Abdelmagid et al. (1996), Alderman and Sahn (1993), Gao and Spreen (1994), Gao et al. (1997), Han and Wahl (1998), Heien and Durham (1991), Nayga (1995, 1996, and 1998), Park et al. (1996), Salvanes and DeVoretz (1997), Wang et al. (1996), and Wellman (1992), and improved by Shonkwiler and Yen (1999). Shonkwiler and Yen proposed a consistent two-step estimation procedure for demand systems with limited dependent variables. Heien and Wessells's (1990) procedure differs as it is built upon a set of equations which deviate from the unconditional mean expressions for the conventional censored dependent variable specification. The procedure proposed by Shonkwiler and Yen (1999) was applied in works of Su and Yen (2000), Yen et al. (2002), Yen et al. (2003), Sckokai and Moro (2009).

The system of equations with limited dependent variables is (Shonkwiler and Yen, 1999):

(19) $$y_{it}^* = f(x_{it}, \beta_i) + \varepsilon_{it}, \qquad d_{it}^* = z_{it}^{'}\alpha_i + v_{it},$$

$$d_{it} = \begin{cases} 1 & \text{if } d_{it}^* > 0 \\ 0 & \text{if } d_{it}^* \leq 0 \end{cases} \qquad y_{it} = d_{it} y_{it}^*, \qquad i = 1, 2,...,n;\ t = 1, 2,..., T$$

where, for the *i*th equation and *t*th observation, y_{it} and d_{it} are the observed dependent variables, y_{it}^* and d_{it}^* are corresponding latent variables, x_{it} and z_{it} are vectors of exogenous variables, β_i and α_i are conformable vectors of parameters, and ε_{it} and v_{it} are random errors with bivariate normal distribution.

Heien and Wessells (1990) first obtained ML probit estimates $\hat{\alpha}_i$ for each of estimated equations *i* that were based on the binary outcomes d_{it} = 1 and d_{it}= 0. In the second stage the researchers estimated the system with estimated expected error (IMR) using Zellner's (1962) seemingly unrelated regression (SUR). The IMR vector discussed in works of Heckman et al. (1998), Heckman (2001), and Greene (2003) and can be generated from the parameter estimates (Greene, 1993);

(20) $$IMR = \phi(k_{it} z_{it}^{'} \hat{\alpha}_i) / \Phi(k_{it} z_{it}^{'} \hat{\alpha}_i)$$

where $k_{it} = 2d_{it} - 1$, $\phi(\cdot)$ is a univariate standard normal probability density function (PDF), and Φ $(\cdot)$ is a univariate standard normal cumulative distribution function (CDF); $z_{it}^{'}$ is the vector of the exogenous variables. In work of Heien and Wessells (1990) IMR was thought to remove the part of the error term correlated with the explanatory variables to avoid the bias, however Shonkwiler and Yen (1999) showed that it is not quite so.

In Shonkwiler and Yen (1999) the whole sample is used in demand system analysis. Assume for each i the error terms $\varepsilon_{it}^{'}$ and $v_{it}^{'}$ have bivariate normal distribution with covariance matrix cov(ε_{it}, v_{it}) = δ_i. Then, the conditional mean of y_{it} is (Wales and Woodland, 1980):

(21) $$E(y_{it}|x_{it}, z_{it};\ v_{it} > -z_{it}^{'}\alpha_i) = f(x_{it}, \beta_i) + \delta_i \frac{\phi(z_{it}^{'}\alpha_i)}{\Phi(z_{it}^{'}\alpha_i)}.$$

Because, $E\left(y_{it}|x_{it}, z_{it};\ v_{it} \leq -z_{it}^{'}\alpha_i\right) = 0$, the unconditional mean of y_i is

(22) $$E(y_{it}|x_{it}, z_{it}) = \Phi\left(z_{it}^{'}\alpha_i\right)f(x_{it}, \beta_i) + \delta_i\phi\left(z_{it}^{'}\alpha_i\right)$$

Based on equation (22) for each i, the system of equations (19) can be written as (Shonkwiler and Yen, 1999):

(23) $$y_{it} = \Phi\left(z_{it}^{'}\alpha_i\right)f(x_{it}, \beta_i) + \delta_i\phi\left(z_{it}^{'}\alpha_i\right) + \xi_{it}, \quad (i = 1, 2,..., m;\ t = 1, 2,...., T)$$

where $\xi_{it} = y_{it} - E(y_{it}|x_{it}, z_{it})$.

The two-step estimation starts with consistent ML probit estimates $\hat{\alpha}_i$ of α_i of each i;[6] then find $\Phi\left(z_{it}^{'}\hat{\alpha}_i\right)$ and $\phi\left(z_{it}^{'}\hat{\alpha}_i\right)$ and finally estimate β_i, δ_i in the system as in Shonkwiler and Yen (1999) and Yen et al. (2002):

(24) $$y_{it} = \Phi\left(z_{it}^{'}\hat{\alpha}_i\right)f(x_{it}, \beta_i) + \delta_i\phi\left(z_{it}^{'}\hat{\alpha}_i\right) + \xi_{it}, \quad (i = 1, 2,..., m;\ t = 1, 2,...., T)$$

[6] When estimating separate probit models, the restriction imposed: $E(v_{it}v_{kt}) = 0$ for $i \neq k$, without the restriction the multivariate probit model would have to be estimated (Shonkwiler and Yen, 1999).

by ML or Iterated Seemingly Unrelated Regression (ITSUR) procedure, where

(25) $$\xi_{it} = \varepsilon_{it} + [\Phi(z_{it}^{'}\alpha_i) - \Phi(z_{it}^{'}\hat{\alpha}_i)]f(x_{it}, \beta_i) + \delta_i[\phi(z_{it}^{'}\alpha_i) - \phi(z_{it}^{'}\hat{\alpha}_i)]$$

and

(26) $$E(\xi_{it}) = 0 \quad \text{with}$$

(27) $$var(\xi_{it}) = \sigma_i^2\, \Phi(z_{it}^{'}\alpha_i) + [1 - \Phi(z_{it}^{'}\alpha_i)] \times \begin{Bmatrix} [f(x_{it}, \beta_i)]^2 \Phi(z_{it}^{'}\alpha_i) \\ +2f(x_{it}, \beta_i)\delta_i\phi(z_{it}^{'}\alpha_i) \end{Bmatrix}$$

$$-\delta_i^2\{z_{it}^{'}\alpha_i\phi(z_{it}^{'}\alpha_i) + [\phi(z_{it}^{'}\alpha_i)]^2\}$$

Because the ML probit estimators $\hat{\alpha}_i$ are consistent, applying SUR estimation to equation (24) produces consistent estimates in the second step (Shonkwiler and Yen, 1999). However the error terms of the equations in two steps are correlated causing the estimates of standard errors to be incorrect (Murphy and Topel, 1985). The error terms are also heteroskedastic (Shonkwiler and Yen, 1999). Shonkwiler and Yen (1999) used Murphy and Topel's procedure to adjust the covariance matrix. Applied by many the bootstrap procedure (Efron, 1979) could also be used to adjust the covariance matrix, a procedure used here and described later.

This model is a generalization of Amemiya's (1974) censored system. Each dependent variable is censored by a discrete (zero or positive) stochastic process, separate probit models.

4.2.1. First stage: Probit regressions

The probability that a given household consumes tomatoes, onions, peppers and fresh okra were estimated using the probit model. These regressions are also used to estimate cumulative density function, and probability distribution function of each respective equation.

The four probit equations are defined such that the decisions to purchase tomato, onion,

peppers or fresh okra are functions of variables representing geographical location of the household; gender; age; religion; education; type of employment of the household head; a variable that identifies whether the household head has paid or unpaid job; distributions of the age groups of the household members; household size; whether household receives food as a gift; and whether it grows own food products, not specifying which exactly; total expenditure. The complete descriptions of the dependent and explanatory variables is in Table 7.

The probit regression for the decision to purchase onion is:

$$(28) \quad Onion\_b = \alpha_0 + \beta_1 \text{Newhhid} + \beta_2 \text{Marriage} + \beta_3 \text{Religion} + \beta_4 \text{Headage} + \beta_5 \text{Giftfood} + \beta_6 \text{Ownfood} + \beta_7 \text{NC} + \beta_8 \text{NE} + \beta_9 \text{NW} + \beta_{10} \text{SE} + \beta_{11} \text{SS} + \beta_{12} \text{Sector} + \beta_{13} \text{School} + \beta_{14} \text{Agact} + \beta_{15} \text{Wage} + \beta_{16} \text{Wellbeingindex} + \beta_{17} \text{Hhsize} + \beta_{18} \text{Young20} + \beta_{19} \text{Middle40} + \beta_{20} \text{Elderly} + \beta_{21} \text{X\_new} + e_{onion}$$

where βs are parameters to be estimated, and e is an independent and identically distributed error term with an expected zero mean and constant variance. The probit models for peppers, tomato and fresh okra differ by dependent variables which represent the decision to purchase the good.

The probit selection model describes how households decide whether to purchase good *i*. The household's decision to purchase one or another type of vegetable is a linear function of a vector of observable covariates (variables (*Z*)) and latent (unobservable) continuous random variables with an assumed standard normal distribution of (e_i) that influence the probability that a household does purchase the selected vegetables. The selection function specifies that if $\alpha_0 + \beta \text{Z} + e_i > 0$, the household will purchase the good; otherwise, the household will not purchase the good.

The parameter estimates from the probit model are transformed to generate estimates of the marginal effects (the change in probability associated with changes in the explanatory variables) (Greene, 2003). The nonlinear functions of the parameter estimates and the levels of the explanatory variables represent the marginal effects (Anderson and Newell, 2003). All the households that have at least one missing value in any of the variables were excluded from the analysis, solely complete-case analysis are used in the probit models.

Assuming the data is normally distributed probit model permits estimation of the marginal or partial effects (Greene, 2003). The marginal effects could be computed in two different ways: (1) at the sample means of the data; and (2) at a sample average of the individual marginal effects of every household.

The marginal effects for a covariate in the probit model is (Greene, 2003) :

(29) $$ME = \frac{\partial \Pr(y=1)}{\partial Z_k} = \phi\beta(Z'\beta)$$

where *y* represents dependent binary variables of purchasing tomato, onion, peppers or fresh okra.

The effects are distinguished between continuouse and dummy variables. The marginal effect of a continues variable (29) could not be used in computation of the effects of binary variables (Greene, 2003). The marginal effects for the independent binary variable (Z_k, for example), holding other variables constant is (Greene, 2003):

(30) $$ME^{binary} = \frac{\Delta \Pr(y=1)}{\Delta Z_k} = E\left(Y = 1 \middle| \bar{Z}_{(Z_{kt})},\ Z_k = 1\right) - E\left(Y = 1 \middle| \bar{Z}_{(Z_{kt})},\ Z_k = 0\right)$$

where $\bar{Z}_{(Z_{kt})}$ is the means of the independent variables in the model.

4.2.2. Multicollinearity

Ignoring collinearity between covariates has a number of consequences: it influences the significance of the variables, changes the signs of the parameter estimates (Belsley et al., 1980; Greene, 1993; O'Brien, 2007). The Variance Inflation Factor (VIF) is widely used to identify multicollinearity problem (O'Brien, 2007). The VIF is defined by Afifi and Clark (1984) and Fox (1984) as:

$$VIF = \frac{1}{1-R^2} \quad (31)$$

where R^2 is the coefficient of the determination or the multiple correlation coefficient (Nagelkerke, 1991).

VIF values higher than 10 indicate a serious multicollinearity problem (Neter et al., 1989; Marquardt, 1970; Mason et al., 1989; Kennedy, 1992). To solve a problem of such a kind one would usually remove or transform the collinear variables (Wooldridge, 2003), or use Ridge Regression for data analyses (Judge et al., 1988). The VIF tests were applied at each stage of the analysis.

4.2.3. Second stage: Iterated Seemingly Unrelated Regression (ITSUR)

As noted by Shonkwiler and Yen (1999) second stage of demand system can be estimated using Maximum-Likelihood (ML) or Seemingly Unrelated Regression (SUR) procedures. ML is computationally complicated procedure due to difficult mutual dependency "between the end points of the integrals in the likelihood function" (Tiffin and Arnoult, 2010). The SUR procedure is widely used in applied demand studies (Shonkwiler and Yen, 1999). The SUR procedure was

chosen to be used in this thesis as the cross-equation restrictions on the coefficients imposed by economic theory induce the simultaneity of demand equation estimation (Henningsen and Hamann, 2007). Such system is more accurate to be estimated using the generalized least squares estimation (GLS) then OLS (Parlow, 2010). The SUR model is known to produce more efficient estimates compare to OLS regression procedures because it treats the equations as a system and uses GLS (Bartels and Fiebig, 1991; Takada et al., 1995). SUR model (Zellner, 1962) was developed for analysis of multiple regression equations that are estimated simultaneously. The model was studied by (Avery, 1977; Baltagi, 1980; Binkley, 1982; Phillips, 1977 and 1985; Srivastava and Dwivedi, 1979). The SUR model allows some of the independent variables to be the same among the estimated equations (Beasley, 2008). The errors among estimated equations may be correlated (Bartels and Fiebig, 1991). ITSUR procedure produces consistent parameter estimates and is “more convenient” to be applied than full information maximum likelihood estimation (Barnett and Seck, 2008). The demand LA/AIDS model for tomatoes, onions, peppers and fresh okra, conditional on the decision to purchase is estimated using Iterated Seemingly Unrelated Regression (ITSUR).

To test if error terms are correlated and the use of SUR regression is justified, use a LaGrange-Multiplier test proposed by Breusch and Pagan (1979) (Parlow, 2010):

$$(32) \quad \lambda_{LM} = T \sum_{i=2}^{n} \sum_{j=1}^{i-1} r_{ij}^2$$

The $H_0 = \sigma_{ij}$. The rejection of null hypothesis will indicate that SUR procedure should be applied, otherwise separate OLS regressions could be used for analysis (Parlow, 2010).

4.3. Model

The models used in consumer demand analysis are Kuhn-Tucker (1951), virtual price approach (Lee and Pitt, 1986, 1987), and Tobin (1958) limited dependent variable model that was expended by Amemiya (1974) for a case of multiple equations. Kuhn-Tucker and Amemiya-Tobin models were estimated by Wales and Woodland (1983) using ML method for meat consumption data from Australia. The authors concluded that the outcome of the analyses was not sensitive to the model used. Following works of Shonkwiler and Yen (1999), and Yen et al. (2003) the Amemiya-Tobin system appears to be preferred by researchers. As noted by Yen et al. (2003), Amemiya-Tobin approach does not have to satisfy the statistical coherency requirements which challenge enforcement of flexibility of functional forms (Soest et al., 1993).

In this analysis the other-vegetables-good was treated as a residual good (Pudney 1989; Yen et al., 2003), with the remaining first four equations analyzed. The other-vegetables-good equation was dropped to avoid the problem of the singularity of the covariance matrix (Attfield, 1985). However, the resulting ML estimates are not invariant with respect to the equation excluded (Yen et al., 2003). On the other hand, as argued by Yen et al. (2003), we are explicitly interested in tomatoes, peppers, onions and fresh okra. Therefore, maintaining the invariance property is not a priority of this analysis.

As shown in Table 9 there are households that do not consume one or more of the analyzed vegetables. The difficulty with recorded zero consumption, also called a limited dependent variable problem (Yen and Roe, 1989), generates two problems (Heien and Wessells, 1988): (1) the estimated budget shares can be outside the zero - one range (Woodland, 1979); (2) no prices could be recorded as zero in complete demand system analysis, however there will be no data on prices if the household did not consume the product. The missing prices were changed

to area means as was discussed earlier.

There are different approaches used by researchers in demand system estimation: Translog Demand system (Christensen et al., 1975), the Rotterdam model (Theil, 1965 and 1976; Barten, 1969), AIDS (Deaton and Muellbauer, 1980a), General Demand System that includes AIDS and Translog systems as special cases (Lewbel, 1989). The actual AIDS model is difficult to estimate because its price index is not linear in terms of parameters estimated. The LA/AIDS model is linear in the unknown parameters and more commonly used in demand analysis (LaFrance, 2004). The AIDS model of Deaton and Muellbauer (1980a, 1980b) has many advantages over rest of the models: (1) the linear approximation of AIDS (LA/AIDS) is not too hard to estimate (Buse, 1994) within Amemiya-Tobin approach (Dong et al., 2004); (2) the model fulfills the axioms of choice theory (Taljaard et al., 2004); (3) according to Park (2010) LA/AIDS has locally flexible functional forms, meaning the model has enough parameters so that the "derivatives of the expenditure function can be" equal to the derivatives of "an arbitrary function" (Shaikh and Larson, 2003); (4) it is easy to impose homogeneity and symmetry constraints simultaneously using estimated parameters (Moschini, 1998); (5) the model aggregates across analyzed households without appealing "parallel linear Engel curves" (Taljaard et al., 2004); (6) it can be used in consumer behavior analysis on macroeconomic level when aggregation across households is used as well as microeconomic level when data on every single household is used (Glewwe, 2001).

The dependent variables are the expenditure shares. The expenditure share for other-vegetables-good was dropped from the estimation as required by the adding-up restriction. The LA/AIDS model differs from AIDS model by the form of the Stone price index suggested by Deaton and Muellbauer (1980a). The LA/AIDS model can be denoted as follows:

(33) $$w_i = \alpha_i^* + \sum_j \gamma_{ij} \ln(p_j) + \beta_i \ln\left(\frac{m}{P^*}\right) + \mu_i^*,$$

and the parameters to be estimated in the model are α, β, and γ. In (33) *i* = tomato, onion, peppers, fresh okra and *j* = tomato, onion, peppers, fresh okra, and other-vegetables; w_i is the budget share of good *i*, $w_i = \frac{p_i q_i}{m_i}$, where m_i is the total expenditure for good *i*; p_j is the price of good *j* (before taking the natural logarithm of prices, the prices were normalized by price means); *m* is the total expenditure of the commodities (onions, peppers, tomatoes, fresh okra and other-vegetables), $m = \sum_k p_i q_i$ for every household *k*; α_i, γ_{ij}, and β_i are parameters; μ_i^* are the random disturbances assumed with zero mean and constant variance; and P^* is the Stone's price index which approximates the ''true'' translog index (Deaton and Muellbauer, 1980a). The translog price index defined as:

(34) $$lnP = \alpha_0 + \sum_i \alpha_i lnp_i + \frac{1}{2}\sum_i \sum_j \gamma_{ij}^* \, lnp_i lnp_j$$

The price index in (34) is difficult to estimate due to the non-linearity of the parameters. The Stone price index which is an approximation proportional to the translog price index is widely used in LA/AIDS model (Asche and Wessells, 1997):

(35) $$ln(P^*) = \sum_i w_i \ln(p_j)$$

However, Pashardes (1993) and Buse (1998) argued that using Stone's index rather than the ''true'' translog price index generates biased and inconsistent parameter estimates. Moschini

(1995) called Stone's index an improper price index. It is often noted that applying Stone's index will cause the units of measurement error (Asche and Wessells, 1997; Moschini, 1995). To solve the problem of unit measurement errors, the prices should be scaled by the means of observed expenditure shares (Moschini, 1995; Bilgic and Yen, 2013). The corrected Stone's price index is obtained by replacing w_i in Equation (35) by mean budget shares, $\overline{w}_i$ (Moschini, 1995):

(36) $$\ln(P^L) = \sum_i \overline{w}_i \ln(p_j)$$

Substitution of Equation (36) into Equation (34) yields a LA/AIDS model with the corrected price index as follows:

(37) $$w_i = \alpha_i^* + \sum_j \gamma_{ij} \ln\left(p_j\right) + \beta_i(\ln(m) - \sum_i \overline{w}_i \ln\left(p_j\right)) + \mu_i^*$$

According to Pollak and Wales (1981) there are several ways to include demographic variables to demand system: (1) demographic translating; (2) demographic scaling (Barten, 1964); (3) the "Gorman procedure" (Gorman, 1976) that combines both scaling and translating; (4) the "reverse Gorman procedure"; and (5) "modified Prais-Houthakker procedure" (Prais and Houthakker, 1955) (Pollak and Wales, 1981). The two most commonly used techniques are demographic translating and scaling (Heien and Wessells, 1990). However the effect of demographic variables could also be seen using a marginal effects approach, also used by Yen et al. (2003) in their work on fruit and vegetable demand in Malaysia.

As shown in section 4.2, following Shonkwiler and Yen (1999) and Bilgic and Yen (2013) the expenditure share equation (37) of the censored system is:

$$(38) \qquad w_i = \Phi_i(\alpha_i^* + \sum_j \gamma_{ij} \ln(p_j) + \beta_i(\ln(m) - \sum_i \bar{w}_i \ln(p_j))) + \delta_i \phi_i + \mu_i^*$$

Where δ_i is the covariance between probit models error terms and share equations. The equations for budget shares of peppers, tomato and fresh okra were constructed in the same way. Besides different dependent variables, the equations differ only by the Φ and ϕ terms.

To impose the restrictions of economic theory—homogeneity, adding-up, and Slutsky symmetry—the constraints are imposed on the parameters of the model. The adding-up condition is:

$$(39) \qquad \sum_i \alpha_i = 1,$$

but the restriction is often not imposed in the cases of censored demand estimation, or imposed by dropping one of the equations from the system (Yen and Lin, 2006; Yen et al., 2003; Kasteridis et al., 2011; Bilgic and Yen, 2013). In this analysis the other-vegetables-good was dropped from the model.

The homogeneity restriction is satisfied when, for all *i*:

$$(40) \qquad \sum_{j=1}^{n} \gamma_{ij} = 0$$

The restriction of $\sum_i \beta_i = 0$ was not imposed as one of the goods was dropped from the analysis, the restriction could be used to find coefficients for the other-vegetables-group.

Even though Deaton and Muellbauer (1980a) cautioned about the symmetry of the matrix

of log-price coefficients, the restriction was implied and tested by Anderson and Blundell (1983), Moschini and Meilke (1989). The symmetry restriction is:

$$\gamma_{ij} = \gamma_{ji}, \quad (41)$$

and implies that cross-price derivatives of the demand functions are indistinguishable (Taljaard et al., 2004). The restriction is implied by the homogeneity condition, see Table 14.

4.4. Bootstrap estimation of the standard errors

Lee et al. (1980) showed that in two-stage model estimation, the standard errors from the second stage always underestimate the correct standard errors and need to be corrected. The bootstrap procedure can generate more accurate standard errors (Hall and Horowitz, 1996). It reduces the sample bias of estimators and sample mean-square errors (Horowitz, 1999). Although the procedure is known for its precision, Horowitz (1999) alerts to use it carefully as for example in estimation of the instrumental-variables with poorly correlated instruments and regressors when estimators have “nearly singular” asymptotic covariance matrices, the bootstrap may perform poorly.

Introduced by Efron (1979), the bootstrap procedure was studied by Beran and Ducharme (1991), Davison and Hinkley (1997), Efron and Tibshirani (1993), Hall (1992), and Shao and Tu (1995), and from the econometric prospective by Hall (1994), Horowitz (1997), Maddala and Jeong (1993) and Vinod (1993).

The bootstrap procedure uses Monte Carlo sampling (Cugnet, 1997). As in Efron and Tibshirani (1993) the bootstrap procedure generates a number (*G*) (*G* = 1,499 in this thesis) of

random samples (x^{*g}), each of the size of original sample *n* (3,033 in this thesis) with replacement[7] from the sample data set. The method causes every new sample to deviate from the original sample; consequently the statistics of interest calculated from each sample will also deviate from the original sample statistics (Cugnet, 1997). The final bootstrap data consists of 4,546,467 observations. The adjusted standard errors for both stages of the estimation are reported in Tables 12 and13. Shown in tables 12 and 13 the adjusted standard errors differ from conventional standard errors, being higher in most of the cases.

The statistics of interest are standard errors on both stages of the analysis. The bootstrap estimate of standard error ($\widehat{se}_{boot}$) is (Efron and Tibshirani, 1993):

$$(42) \qquad \widehat{se}_{boot} = \left\{\sum_{g=1}^{G}[s(x^{*g}) - s(\cdot)]^2 /(G-1)\right\}^{\frac{1}{2}}$$

where *s* is the bootstrap value of the statistics evaluated for x^{*g}. For example if *s(x)* is the sample mean, then $s(x^{*g})$ is the mean of the bootstrap sample.

From the standard probability theory, when *G* is as large as in this thesis, (42) takes the form (Efron and Tibshirani, 1993):

$$(43) \qquad \widehat{se}_{boot} = \{\sum_{i=1}^{n}(Z_i - \bar{Z})^2 /n^2\}^{\frac{1}{2}}$$

When large *G* is used, the estimates relative frequency distribution will be more precise (Cugnet, 1997).

[7] The term replacement means that some of the observations could be selected multiple times while others could be never chosen.

4.5. Demand Elasticities for the censored LA/AIDS model

The expenditure shares cannot be negative or exceed unity. The expected budget shares used in calculation of the elasticities using ad hoc procedure: $w_i^{**} = 0$ if $w_i^{*} \leq 0$ and $w_i^{**} = 1$ if $w_i^{*} > 1$, otherwise $w_i^{**} = w_i^{*}$, where w_i^{*} corresponds to expected budget shares and w_i^{**} are adjusted expenditure shares. When systems are evaluated at the point of the normalized price, the LA/AIDS and AIDS models were found by Asche and Wessells (1997) to be identical. A variety of literature exists on demand elasticities derivation for the AIDS and LA/AIDS models. As in Buse (1994), Chalfant (1987), Green and Alston (1990), and Alston et al. (1994) the expenditure elasticity could be derived from the LA/AIDS model by taking the derivative with respect to ln(m):

(44) $$\eta_{im} = 1 + \left(\frac{1}{w_i}\right)\left(\frac{\partial w_i}{\partial \ln(m)}\right) = 1 + \left(\frac{\beta_i}{w_i}\right)$$

The formula (44) was found by Green and Alston (1991) to be incorrect for the LA/AIDS model. The correct formula, according to Buse (1994), could be written in two forms:

(45) $$\eta_{ix}(L_1) = 1 + \left(\frac{\beta_i}{w_i}\right)\left[1 - \frac{\sum_k \beta_k lnp_k}{1+\sum_k \beta_k lnp_k}\right]$$

(46) $$\eta_{ix}(L_2) = 1 + \left(\frac{\beta_i}{w_i}\right)\left[1 - \sum_k \beta_k lnp_k\right]$$

Asche and Wessells (1997) noted that at the point of normalization (45) becomes (44).

Using the AIDS and LA/AIDS models, the general form of the uncompensated demand

elasticities are (Green and Alston, 1990):

$$(47) \qquad \eta_{ij} = -\delta + (\gamma_{ij} - \beta_i \frac{dlnP}{dlnpj})/w_i$$

To derive uncompensated own ($i = j$) and cross ($i \neq j$) price elasticities η_{ij}, the formula used by Chalfant (1987) is:

$$(48) \qquad \eta_{ij} = -\delta_{ij} + \left(\frac{\gamma_{ij}}{w_i}\right) - \left(\frac{\beta_i}{w_i}\right)\left(w_{jt} + \sum_{j=1}^{n} \gamma_{ij}\, lnp_{jt}\right) \times \left(1 + \sum_{j=1}^{n} \beta_j\, lnp_{jt}\right)$$

At the point of normalization, (48) becomes (Asche and Wessells, 1997; Alston et al., 1994):

$$(49) \qquad \eta_{ij} = -\delta + \left(\frac{\gamma_{ij}}{w_{it}}\right) - \left(\frac{\beta_i}{w_{it}}\right) w_j,$$

where δ_{ij} is the Kronecker delta, equaling to unity when $i = j$, and zero when $i \neq j$. The elasticities in empirical literature are reported at a particular point, the most common being at the mean. In this thesis the elasticities were calculated for every individual household as each of them has own distinguished cumulative distribution function that is included in formulas of elasticities. To report the elasticities for whole Nigerian society the mean elasticities were estimated across 3,033 representative households (Tables 15 and 16).

At the point of normalization the compensated, Hicksian price elasticities e_{ij}^{com} for every household are (Green and Alston, 1991; Asche and Wessells, 1997):

(50) $$\eta_{ij}^{com} = \eta_{ij} + \eta_i w_j = -\delta_{ij} + \left(\frac{\gamma_{ij}}{\mathrm{w}_i}\right) + \mathrm{w}_j$$

Similar to Yen et al. (2002), who derived the elasticities for Translog demand system addressing censoring issue, incorporating Φ_i to (49) yields:

(51) $$\eta_{ij} = -\delta + \left(\Phi_i \frac{\gamma_{ij}}{w_i^{**}}\right) - \left(\Phi_i \frac{\beta_i w_j^{**}}{w_i^{**}}\right),$$

which is consistent with Akbay et al. (2007). When taking a derivative of (38) by $\ln p_j$, keeping in mind special case $\frac{dlnP^*}{dlnp_j} = w_j$ (Green and Alston, 1990) when expenditure shares are treated as constants, one notices that Φ_i always influence γ_{ij} and β_i. Then (44) and (50) can be rewritten as (52) and (53), respectively:

(52) $$\eta_{im} = 1 + (\Phi_i \frac{\beta_i}{w_i^{**}})$$

(53) $$\eta_{ij}^{com} = -\delta_{ij} + \left(\Phi_i \frac{\gamma_{ij}}{w_i^{**}}\right) + w_j^{**}$$

As noted previously the uncompensated, compensated price elasticities, and income elasticities for good *i* are η_{ij}, η_{ij}^{com}, and η_{im}, respectively. The elasticities from the restrictions, the Cournot and Engel aggregation conditions could be written as follows (Silberberg and Suen, 2001; Yen et al., 2003):

(54) $\sum_{i=1}^{n} w_i \eta_{im} = 1$

is also known as "Engel aggregation restriction" and is derived from the adding-up condition

(55) $\sum_{i=1}^{n} w_i \eta_{ij} + w_j = 0$

(56) $\sum_{i=1}^{n} w_i \eta_{ij}^{com} = 0$ for j = 1, ..., n.

From the homogeneity restrictions (Yen et al., 2003):

(57) $\sum_{j=1}^{n} \eta_{ij} + \eta_{im} = 0$

(58) $\sum_{j=1}^{n} \eta_{ij}^{*} = 0$ for all i

The demographic variables are not directly involved in the computation of the elasticities in either AIDS or LA/AIDS models (Liu and Chern, 2001).

CHAPTER 5: RESULTS

5.1. Sample structure

As described in details in Appendix B the sample design was based on 500 EAs, 5,000 households were interviewed during the post-harvest and post-planting visits to Nigeria. After the data cleaning and modification, 3,033 households that were kept in the final sample data represented 481 EAs, 322 LGAs, 36 states plus the Federal Capital Territory, Abuja, and six geographic zones of the Federation of Nigeria. As shown in Table 8 different numbers of households from rural and urban areas, from different enumeration areas, local governmental areas, states and zones were used in this study. 18.7% of households were from North-Central zone, 19.4% from North-East, 21.9% from North-West and only 7.5% were from South-Eastern zone, South-South zone were represented by 15.0% of the households in analysis, the rest 17.4% were from South-West zone.

Kearney (2010) noted that the change in consumer behavior and nutritional diets are sensitive to culture, beliefs and religious traditions, urbanization, diversity in diets of rural and urban citizens among other reasons. The majority of the households, 2,120 (about 70.0%) were from rural areas. There were more households in rural than in urban areas in almost every geographic zone. The only exception is the South-Western zone where there were by more than twice as many households in urban area as it was in rural. 51.2% of the sampled households belong to Islam religion, whereas rest of the households reported Christianity, traditional or other.

Consistent with the pattern across much of Sub-Saharan Africa, Nigerian women play an important role in agricultural activities, accounting for 60.0% - 80.0% of the agricultural work force (Bzugu and Kwaghe, 1997). The female-headed households represent only 11.5% of the

sample and 7.1% of them live in rural areas. The female-headed households are not concentrated in one geographic zone. They could be seen in all six zones used in the analysis, with the most of them 102, corresponding to 22.4% of the households of the South-South zone and 98 or corresponding to 18.5% of the households of South-West zone. The least of the female-headed households (9) are present in North-West zone and account for only 1.4% of the total number of households in the zone. The heads of the households are mostly male, as it is common rule ―if there is a male adult in the household, he will automatically be known and recorded as a household head, despite his involvement in household activities.

The age of the household heads varied a lot, most of them (229) were 40 years old. Around 13.0% of the households have four, five or six household members, 11.0% of the households have seven members and 9.0% include just three people. The majority of the household heads (84.2%) is married or live in union. In his study from Nigeria Nwakoby (1994) found that among mainly agricultural population of 488 women, 17.0% of them were in polygamous marriages. It is also known that sometimes female spouses ask male household heads to have another wife as it is seen as an additional free labor force. As for education, 67.3% of the household heads attended school. The variable, education that showed whether household head had only school education or higher was dropped from the analysis due to a large number of missing values and its overlap with the binary variable that reflects whether the household head attended school at all.

About 56.0% of the household heads have recorded agriculture as their primary activity, only 27.5% of them receive a wage, it is common that much of agricultural work is performed by household members. Most of the household heads (70.8%) who have occupations in other sectors like mining, manufacturing and others receive wage, overall 46.4% of the household

heads have a paid job. From all of the households present in the analysis only 11.5% receive food as a gift and more than half of them (55.4%) grow own food products.

The wellbeing index of the households (see Tables 4, 5 and 6) ranged from fifteen to a hundred, representing households that have only one of the index components and households that have durable material used for their dwellings, available electricity, radio, tv, computer, good source of drinking water and rest of the index components. The median index is 65 among all the households in the sample.

As recorded in Table 9, not every household consumed all of the vegetables present in analysis. Onions were consumed by most of the households (80.3%) with the average quantity purchased of 1.02 kg per household. Peppers were consumed by 67.9% of the households with the mean consumption of 0.89 kg. Tomatoes were purchased by 66.7% with the average consumption of 2.19 kg. Nearly same percentage (64.6%) of the households consumed other-vegetables that included consumption of eggplant, leaves (cocoyam, spinach etc.), cassava, yam and cocoyam, white and yellow gari, potatoes and sweet potatoes, and other roots and tubers with the mean of 4.56 kg. The least consumed product in the sample was fresh okra, consumed by 28.6% of the households with average 0.76 kg purchased per household.

The weekly income spent for the five types of vegetables ranges from almost nothing, N0.002 to N6,000 with the mean of N425.50 ($2.63). The average expenditure for onion was N102.38, for peppers, fresh okra, tomato and other-vegetables the mean expenditures were N127.40, N80.66, N142.50, N219.62, respectively. The mean expenditure shares in the sample are similar among onion, peppers, tomato and other-vegetables, being 0.24, 0.20, 0.23 and 0.27, respectively, the smallest mean budget share of 0.06 belongs to fresh okra.

The prices recorded for every interviewed household ranged a lot in a sample. The mean

prices, calculated at the national level across all the state, areas and zones, not taking into consideration any inserted mean prices were N161.57, N399.67, N130.00, N83.07, N45.23 for onion, peppers, fresh okra, tomato and other-vegetables, respectively.

5.2. Multicollinearity Diagnostics

The multicollinearity results are presented in Tables 10 and 11. As all of the independent variables in probit models are identical their VIF scores are equal between each other, the mean VIF at the first stage is 2.06. The highest VIF was for the fraction of young household members (3.4), the same among all probit models. The mean VIF scores at the second stage of the analysis were different across the models as every model has different deterministic PDF. The mean VIF scores are 1.44, 1.41, 1.35 and 1.34 for onion, peppers, tomato and fresh okra, respectively. The highest VIF at the second stage of the analysis was for the logarithm taken of normalized price of fresh okra, being 1.72 in peppers and fresh okra regressions, 1.69 in tomato, and 1.68 in onion regression.

There was no collinearity problem detected by the means of VIF test. None of the VIF scores were higher or close to 10. The multicollinearity of this level is unlikely to affect the coefficients of estimation.

5.3. Results of Probit Regressions

The results of probit models can be found in Table 12. Besides the coefficients, their standard error and adjusted standard errors using bootstrap estimation, the table presents the Likelihood Ratio (LR) Chi-Square (χ^2) test of whether all regression coefficients of the predictors in the model are simultaneously zero expressed by the log likelihood of the fitted

model. LR χ^2 test that at least one of the predictors regression coefficient is not equal to zero.

Every model has same degrees of freedom, because every probit model has same, 21, predictors or independent variables. The probability reported is the probability of obtaining a LR statistic of 101.55, 258.63, 216.49, and 664.66 in onion, peppers, fresh okra and tomato regressions, respectively, or one more extreme if there is in fact no effect of the predictor variables. This p-value is compared to a specified α level, our willingness to accept a type I error, which is by default set at 0.05. As p-values from the LR tests for every model are very small, <0.0001, there is enough evidence to conclude that at least one of the regression coefficients in the model is not equal to zero. All four models fit the data very well ($p < 0.0001$), different combination of independent variables are statistically significant at the 1.0%, 5.0% and 10.0% levels. All independent variables used in analysis, besides age of the household head were significant in at least one of the probit models. The onion equation has the least number of significant determinants in the model, whereas all other products have more than a half of the variables significant at different levels.

Different from OLS probit model does not have an equivalent of R^2, the pseudo R^2 reported in the Table 12 is the McFadden's pseudo R^2. Pseudo R^2 cannot be interpreted as a proportion of variance of the depended variable explained by the independent variables. In case of McFadden's pseudo R^2 the total sum of squares is the log likelihood of the intercept model, and the sum of squared errors is the log likelihood of the full model. The ratio of the likelihoods shows the improvement of full model over the model with only intercept. A likelihood value is between 0 and 1, whereas the log of a likelihood is less than or equal to zero, all log likelihood values are negative in Table 12. The reported small ratios of log likelihoods suggest that the full models are far better fit than the intercept models. The classification command produce a cross-

tabulation of observed and predicted outcomes, where one predicts a positive outcome if the probability is 0.5 or more and a negative outcome otherwise. The models predict correctly 80.3%, 69.6%, 71.6%, and 73.1% of the cases in onion, peppers, fresh okra, and tomato regressions, respectively.

5.4. Marginal effects

In binary regression models, the marginal effect is the slope of the probability curve that shows the relationship of independent variables X_k to Pr(Y=1|X), holding all other variables constant at their means. The results of marginal effects are presented in Table 17.

5.4.1. Onion

Consumed by most of the households in the sample, the decision to purchase onions was correlated with the least number of demographic variables. The marginal effects indicate that besides the income and wellbeing index, the gender of household head, marital status, religion, whether the household grows own food, fractions of young or middle age members also play a significant role in onion consumption.

The marginal effects suggest that the probability of purchasing onion, ceteris paribus, is 5.6% lower for the households located in South-South zone than households in the referenced South-Western zone. All else equal, married household heads have 5.6% greater probability in purchasing onions than households with heads who are single and do not live in any kind of union. Holding all other factors constant, for every percentage increase of young people (below 20 years old) and middle age (21-40 years old) members in total number of household members (as an example — a number of young members divided by the size of the household) corresponds to an increase in the probabily of purchasing onions by 11.9% and 9.5%,

respectively. All else equal, male heads of the households have 8.8% lower probability of purchasing onions than female household heads. The households that produce its own foods are 4.4% more likely of purchasing onion than those that do not grow any agricultural commodities, ceteris paribus. Holding all other factors constant, the households that reported Islam as their religion have a 5.7% lower probability of purchasing onion then household heads in either Christian, traditional or other religious affiliation. Ceteris paribus, a 1.0% increase or decrease in wellbeing index leads to 0.2% increase or decrease in the probability of purchasing onion. All else equal, income is significant at 1.0% level however the positive impact on probability of purchasing onion is very small and almost undetectable.

5.4.2. Peppers

A positive effect on probability of purchasing peppers is observed in income, sector, marital status, and fraction of middle age and elderly household members, whereas determinants like gender of the household head, gift food, NC, NE, NW, SS, primary activity of the household head and size of the household have significant but negative effects.

The marginal effects suggest that the probability of purchasing peppers, ceteris paribus, is lower for the households located in North-Central, North-East, North-West and South-South zones by 17.6%, 16.3%, 10.3%, and 21.3%, respectively, than for the households in the South-Western zone. All else equal, the households from urban areas have 4.3% higher probability of purchasing peppers than the household located in rural areas. Holding all other factors constant, married household heads have 7.1% greater probability in purchasing peppers than households with heads who are single and do not live in any kind of union. All else equal, male-headed households have 11.6% lower probability of purchasing peppers than female-headed households. The households that receive food as a gift, ceteris paribus, have 7.6% lower probability in

purchasing peppers than the households that do not receive food presents. Consistent with other finding the size of the household has a negative effect on the household's probability in purchasing decisions. Holding other variables constant, one additional household member decreases the probability of purchasing peppers by 0.9%. All else equal, the household heads whose primary activity is in agricultural sector has 5.7% lower probabily to consume peppers than the household heads employed in construction, education, health and other sectors. Holding all other factors constant, for every percentage increase of elderly (over 60 years old) members in total number of household members corresponds to an increase in the probabily of purchasing peppers of 14.6%. All else equal, the total income spent on purchasing onion, peppers, tomato, okra and other-vegetables play significant but small positive role on the choice to consume peppers.

5.4.3. Fresh Okra

The marginal effects for fresh okra show that the households from North-Central, North-East, South-East and South-South zones, ceteris paribus, have 14.9%, 5.0%,10.3%, and 17.7%, respectively, higher probability to consume fresh okra than the households in the South-Western zone. All else equal, the households from urban areas have 4.5% higher probability of purchasing fresh okra than the household located in rural areas. Holding all other factors constant, married household heads have 8.1% greater probability of purchasing fresh okra than single household heads. Ceteris paribus, a 1.0% increase in wellbeing index leads to 0.2% increase in the probability of purchasing fresh okra. The households that grow their own food products, other variables held constant, have a 6.0% higher probability of purchasing okra than those that do not have own food production. All else equal, when the head of the household has a paid job, the household has a 4.6% higher probability of purchasing okra than the household

which head does not receive wage. One additional household member, ceteris paribus, decreases the probability of purchasing okra by 1.2%. All else equal, the change in income has positive but very small impact on probability of purchasing fresh okra.

5.4.4. Tomato

Holding other variables constant, the marginal effects for tomato revealed that the households from North-Central, North-East, South-East and South-South zones have 29.7%, 23.4%, 16.8%, and 51.5%, respectively, lower probability of purchasing tomato than the households from the South-Western zone. All else equal, the households from urban areas have 6.6% higher probability of purchasing tomatoes than the household located in rural areas. Male-headed households, ceteris paribus, have 9.8% lower probability of purchasing tomato than the households with female heads. Significant at 1.0% level religion has a positive impact on the probability of the households purchasing tomatoes. The household with Islamic affiliation, holding all other predictors constant, have 7.9% greater probability of purchasing tomatoes than the households affiliated with other religions. All else equal, the households that produce own food have 5.0% greater probability of purchasing tomato than those that do not. The households that receive food as a gift, ceteris paribus, have 5.0% lower probability in purchasing tomatoes than the households that do not receive food presents. An increase of household size by one additional person, ceteris paribus, decreases the probability in purchasing fresh okra by 1.0%. The household head who attended school, ceteris paribus, have 9.3% greater probability of purchasing tomato than the household heads who have never attended school. All else equal, total income is significant at 1.0% however the impact on probability of purchasing tomato is very small, lower than 0.1%. Ceteris paribus, a 1.0% increase in wellbeing index leads to 0.6% increase in the probability of purchasing tomato. Holding all other factors constant, for every

percentage increase of young members in total number of household members corresponds to an increase in the probabily of purchasing tomato of 12.6%.

5.5. LA/AIDS model

The estimated parameters of the LA/AIDS model are presented in Table 13. Most of the coefficients are significant in the model at 1.0%, 5.0% and 10.0% levels. The reported αs do not sum to one as other-vegetables-good was dropped from the analysis to avoid the problem of matrix singularity, the constraint could be used to find α value for the dropped good. Significant at 1.0% level δ coefficients that represent the covariance between error terms from probit equations and those of budget share equations imply that there was a selection bias in the model. We may conclude that the values of the budget shares are correlated with the household decision of purchasing the product. The results of Breusch-Pagan test (all Pr > χ^2 are <0.0001) suggest that the standard errors of the parameter estimates are incorrect, the null hypothesis of no error correlation has to be rejected, and the use of ITSUR procedure is justified.

The Likelihood-ratio test statistics, $LR = -2(L_R - L_U)$ where L_R is the maximum value of the log likelihood of restricted model and L_U is the maximum value of the log likelihood of unrestricted model is presented in Table 14. The $p < 0.001$ indicates that the model with restrictions imposed fits data significantly better than the unrestricted model.

5.6. Elasticities

To evaluate the effects of prices and total expenditure on consumption behavior of households in Nigeria addressing data censoring, the demand elasticities were calculated for every household in the sample and mean of these estimates was taken across all households.

Tables 15 and 16 represent uncompensated, compensated and expenditure elasticities, standard errors approximated by bootstrap method, and the lower 5 and upper 95 percentiles of the elasticity means. The lower and upper percentiles are reported since they do not have a certain distribution and represent the lower and upper borders of the elasticity means. The elasticities that have zero values included in 90.0% confidence interval, such as okra expenditure elasticity, uncompensated cross-price elasticities peppers-okra, peppers-tomato, tomato-onion, tomato-peppers, and tomato-okra indicate that elasticities are not much different from zero.

5.6.1. Marshallian Own and Cross Price Elasticities

The Marshallian own and cross price elasticities are presented in Table 15. All own-price elasticities are negative and significant at the 1.0% level, besides fresh okra. All of the own-price elasticities are less than unity in absolute values. The elasticities for onion, peppers, fresh okra, and tomato indicate that the demand is inelastic. The absolute values of the elasticities are close to unity, onion (-0.986), fresh okra (-0.912), peppers (-0.852), and slightly lower for tomato (-0.794) indicate that when products own price changes the demand for those vegetables changes almost proportionally.

According to results of the cross-price elasticities, onion, peppers, tomato and fresh okra are a combination of gross complements and substitutes. The vegetables are primarily gross substitutes. However, the negative cross-price elasticity for tomato and peppers in both directions suggest that those vegetables are gross complements. It is interesting to note that peppers are gross complements for onion whereas onion is gross substitute for peppers. In fact, peppers are the substitute only for fresh okra and gross complement for other goods. Onion and fresh okra are substitutes for all goods used in analysis. If the price of fresh okra increases (decreases), the quantities demanded of all other vegetables increase (decreases) indicating that all vegetables are

gross substitutes with okra that can be explained by the not persistent availability of okra in the market.

5.6.2. Expenditure Elasticities

Expenditure elasticity of demand reflects the relationship between percentage change in income and the percentage change in the demand for the good. The Marshallian expenditure elasticities are presented in Table 15. All income elasticities are positive and significant at 1.0% level, besides for fresh okra. Positive elasticities suggest that tomatoes, onion, and peppers are normal goods. Negative expenditure elasticity for fresh okra implies that with income growth the expenditure for fresh okra will decrease. Fresh okra is an inferior good in this case. Browne et al. (2007) also found negative expenditure elasticity for food group. Expenditure elasticities are greater than unity for peppers and tomato and less than unity for onion and fresh okra in absolute values. The results suggest that with income growth, the expenditures for analyzed vegetables are going to increase, primarily increasing in tomato, peppers, and onion and decrease for fresh okra. The large expenditure elasticity for peppers and tomato suggest that the quantity demanded for those vegetables will increase more than proportionately to the increase in total expenditures.

5.6.3. Hicksian Own and Cross Price Elasticities

The compensated own and cross price elasticities are presented in Table 16. All compensated own price elasticities, without exceptions, are negative and below unity in absolute values. The largest elasticity is for okra at -0.837 whereas smallest is for tomato at -0.539. Consistent with the results for unconditional own price elasticities, all Hicksian own price elasticities besides for fresh okra are significant at 1.0% level.

The uncompensated cross-price elasticities indicated a mix of gross complements and substitutes, while positive values of all Hicksian cross-price elasticities suggest that all

four vegetables are net substitutes. The compensated cross-price elasticities are noticeably smaller than the compensated own-price elasticities in their absolute values. Most of the compensated cross-price elasticities are significant at 1.0% level.

CHAPTER 6: CONCLUSIONS

Rich in natural resources and agro-ecological diversity, Nigeria has a lot of potential in food markets. The predominant food items in the Nigerian diet are starchy staple foods however vegetables play an important role as essential sources of proteins, vitamins, minerals, and amino acids. In this analysis, the effects of prices, income, and demographic characteristics on demand for onion, peppers, fresh okra and tomato were evaluated. GHS data collected by World Bank and Nigeria National Bureau of Statistics, a sample of 3,033 households from rural and urban areas, from different enumeration areas, local governmental areas, states and zones was used in this study. The issue of zero consumption was addressed by using censored demand system estimator in LA/AIDS model and elasticity calculation.

Twenty one demographic variables used in analysis with exception of age of the household head played a significant role in determination of probability of purchasing goods of the focus in this study. The revealed analysis show that when holding all other factors constant, for every percentage increase of young members in total number of household members corresponds to an increase in the probability of purchasing onion and tomato. As was expected the household members of different age group have different consumption preferences, elderly group commonly knows the healthy composition of the goods and tends to provide it for the young household members. Consistent with previous works of Pérez (2002), Rasmussen et al. (2006) and Vereecken et al. (2004), and contrary to recent analysis of Peltzer and Pengpid (2012), gender of the household head played a significant role in decision of purchasing onion, peppers, and tomato, indicating lower probability in purchasing those vegetables for male-headed households. The binary variables of household locations in different geographical zones of Nigeria were found to be significant and had different positive and negative relations to the

probabilities of purchasing one or another vegetable. Such findings imply that food policy and programs that are focused on improving healthy diet need to vary across the regions and need to be carefully implemented in different geographical zones of the country, as households in different locations tend to have different consumption patterns. Seldom found in previous studies the education, expressed using dummy variable of school attendance by the household head was significant only in tomato model. Consistent with empirical studies, the size of the household was found to have significant and negative correlation with vegetable consumption, not taking into account onion. Educational programs that are focused on better nutrient, fruit, and vegetable consumption should take into account demographic characteristics of the regions.

A price change affects the vegetable demand in Nigeria, where large portion of population lives on less than US$1.25 a day (IFAD, 2012). Cross-price elasticities found in the study suggest that onion, peppers, tomato and fresh okra are a combination of gross complements and substitutes. It is interesting to note that peppers are gross complements for onions whereas onions are gross substitute for peppers. Mostly insignificant, the Marshallian cross-price effects are less visible than own-price and expenditure effects.

Economic factors are very important in determining the demand for fruits and vegetables in Sub-Saharan Africa (Ruel et al., 2005). Expenditure elasticities indicated that tomato, onion, and peppers are normal goods, whereas okra fresh appears to be inferior good. Large expenditure elasticities for peppers and tomato suggest that if households in Nigeria had greater purchasing power, they would increase their demand for those goods significantly. Positive changes in income would cause increase in expenditure shares for onion, peppers and tomato, but not okra. In descending order the demand would be changing faster for tomato, peppers, and onion.

Empirical literature has enough evidence on positive health implications of fruits and

vegetable consumption. More than a half of the households used in analyses reported own production of food goods. It is widely known that growing fruits and vegetables would benefit the household, unfortunately weather conditions, floods and dry seasons do not let Nigerian households ensure the proper consumption of the vegetables all year round.

The results found in this study have implications for local Nigerian food producers, retailers, logistic managers, other participants in the food sector, and government food policy makers. There is no single policy that would lead to proper vegetable consumption meeting WHO minimum requirements, however a combination of policies that increase purchasing power of population, and fosters food supply would benefit a developing country, like Nigeria, the most. Expenditure elasticities suggest that with greater purchasing power the demand for peppers and tomatoes increases in a faster pace however in a long run demand for onion will also increase. The lack of steady availability of vegetables in the market due to floods, dry seasons, and transportation loses but also production decisions have their effects on vegetable demand in the country. Increased supply would trigger an increase in quantity demanded, improving livelihood of agricultural producers, poor households and potentially creating more jobs in agricultural and related industries like processing, enabling longer storage of the food goods, or better packaging, minimizing transportation loses.

Rich GHS data provides an opportunity to analyze different aspects of demand analysis. The demand for food and, not considered in this study, non-food goods, food demand for aggregated food groups and many other opportunities for further research.

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APPENDICES

APPENDIX A: How to attain copies of the data

The data is available through the NBS web site: http://www.nigerianstat.gov.ng/
or through the LSMS-ISA website: http://www.worldbank.org/lsms-isa

To receive the copies of the data users are required to fill in a data access agreement. There exist several conditions in this agreement: (a) cite the National Bureau of Statistics as the collector of the data in all reports, publications and presentations; (b) provide copies of all reports publications and presentation to the National Bureau of Statistics (see address below) and the Poverty and Inequality Division of the World Bank (see address below); and (c) not pass the data to any third parties for any reasons.

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Source: Nigeria National Bureau of Statistics. 2012. General Household Survey – Panel. Basic Information Document. International Food Policy Research Institute & National Bureau of Statistics.

APPENDIX B: The GHS Sample Design

"The sample is a two-stage probability sample:

First Stage:

The Primary Sampling Units (PSUs) were the Enumeration Areas (EAs). These were selected based on probability proportional to size (PPS) of the total EAs in each state and FCT, Abuja and the total households listed in those EAs. A total of 500 EAs were selected using this method.

Second Stage:

The second stage was the selection of households. Households were selected randomly using the systematic selection of ten (10) households per EA. This involved obtaining the total number of households listed in a particular EA, and then calculating a Sampling Interval (S.I) by dividing the total households listed by ten (10). The next step was to generate a random start 'r' from the table of random numbers which stands as the 1st selection. Consecutive selection of households was obtained by adding the sampling interval to the random start.

Determination of the sample size at the household level was based on the experience gained from previous rounds of the GHS, in which 10 households per EA are usually selected and give robust estimates.

In all, 500 clusters/EAs were canvassed and 5,000 households were interviewed. These samples were proportionally selected in the states such that different states had different samples sizes" (NBS, 2012).

Source: Nigeria National Bureau of Statistics. 2012. General Household Survey – Panel. Basic Information Document. International Food Policy Research Institute & National Bureau of Statistics.

APPENDIX C: Tables 1 – 17

Table 1. Units of Measure

Type of Measure	Weight	Type of Measure	Weight	Type of Measure	Weight
Sack/Bag		Bunch of Plantains/FFB		Wheel Barrow	
Small	20 kg	Small	5 kg	Small	60 kg
Medium	50 kg	Medium	8 kg	Medium	85 kg
Big/Large	100 kg	Big	15 kg	Big/Large	110 kg
Extra Large	120 kg			Extra Large	150 kg
Basket		Tuber of Yam		Pick-up Van	
Small	15 kg	Small	3 kg	Small	1,500 kg
Medium	30 kg	Medium	5 kg	Medium	2,000 kg
Big	50 kg	Big/Large	8 kg	Big	2,500 kg
Extra Large	75 kg				
Basin		Bundle of Millet, G/Corn, Sugarcane, Vegetables, etc		Jerry can, Keg, Rubber of Palm oil	
Small	10 kg	Small	15 kg	Small	10 Lt.
Medium	25 kg	Medium	25 kg	Medium	20 Lt.
Big/Large	40 kg	Big	40 kg	Big	25 Lt.
Extra Large	75 kg			Large	50 Lt.
				Drum	200 Lt.
Basic units					
Kilogram	1 kg				
Gram	0.001 kg				
Liter	1 lt				
Milliliter	0.001 lt				
Piece	numeral				

Source: Nigeria General Household Survey

Table 2. Correspondence of certain units of measurement to the commodity items

Units of measurement	Items
Bunch of plantains/FFB	Plantains, bananas, other fruits
Tuber of Yam	Cassava roots, yam roots, white and yellow gari, cocoyam, sweet potatoes, potatoes, other roots and tuber
Jerry can, Keg, Rubber of Palm oil, liters and milliliters,	Palm oil, groundnuts oil, fresh milk, bottled water, sachet water, malt drinks, soft drinks, fruit juice, other non-alcoholic and alcoholic drinks, beer, palm wine, pito, gin

Table 3. Kcal consumption

Items (FAO FBS)	Items (Data table)	Food supply quantity (kcal/kg)	Food supply (kcal/capita/day)	Food supply (kcal/capita/week)
Wheat	Wheat flour	2,698	153	1,071
Cereals excluding Beer + (Total)	Yam & Cassava flour	3,069	1,199	8,393
Cereal, other	Other grains and flour	2,433	2	14
Rice (Milled Equivalent)	Rice local & imported	3,720	213	1,491
Maize	Maize, Maize flour	3,178	256	1,792
Millet	Millet	2,943	279	1,953
Sorghum	Guinea corn/sorghum	2,934	295	2,065
Cassava	Cassava roots	803	226	1,582
Potatoes	Potatoes	672	7	49
Sweet Potatoes	Sweet Potatoes	971	33	231
Yams	Yam roots	1,001	246	1,722
Roots, Other	Cocoyam, other roots and tuber	857	27	189
Sugar & Sweeteners + (Total)	Sugar, jams, honey, other sweets and confectionary	3,546	102	714
Pulses, Other	Other nuts, seeds & pulses	3,360	81	567
Soya beans	Soya, white & brown beans	4,056	30	210
Groundnuts	Groundnuts	5,323	35	245
Vegetable Oils + (Total)	Butter (margarine), other oil & fat	8,741	364	2,548
Palm Oil	Palm oil	8,760	120	840
Tomatoes	Tomatoes & tomato puree	196	5	35
Onions	Onions	332	4	28
Other Vegetables	Eggplant, pepper, fresh okra & dried, leaves (spinach, cocoyam etc) & other vegetables	266	28	196
Plantains	Plantains & bananas	893	46	322
Pineapples	Pineapples	275	4	28
Other Fruits	Mangoes, orange, avocado pear, fruit canned & other fruits	403	17	119
Groundnut Oil	Groundnuts oil	8,776	113	791
FAO Total			2,711	18,977

Source: Food Balance Sheet, Nigeria (FAOSTAT, 2009)

Table 4. Components of the Wellbeing Index

Components	Materials and availability
Walls	Predominant material
0	Grass, mud, compacted earth, iron sheets, other
1	Mud brick (unfired)
2	Wood
3	Burnt bricks, concrete
Floor	Predominant material
0	Sand/dirt/straw, smoothed mud, other
1	Smooth cement, wood
Roof	Predominant material
0	Grass, iron sheets, other
1	Plastic sheeting, asbestos sheet
2	Clay tiles, concrete
Electricity	Electricity working in the dwelling
0	No
1	Yes
Bathrooms	Kind of toilet facility
0	None, pail/bucket, other
1	Covered pit latrine, uncovered pit latrine, v.i.p latrine
2	Toilet on water, flush to sewage, flush to septic tank
Rooms	Separate rooms (bathrooms, toilets, storerooms, or garage are not included)
0	No rooms
1	One or two rooms
2	Three rooms
3	Four or five rooms
4	More than five rooms
Property	Own, provided by an employer, rent dwelling
0	Free, not authorized
1	Employer provides, free, authorized, rented
2	Owned
Water source	Main source of drinking water
0	River/spring, lake/reservoir, rain water, other
1	Well/spring unprotected, tanker/truck/vendor

Table 4. Continued

Water source	Main source of drinking water (Continued)
2	Pipe borne water untreated, bore hole/hand pump, well/spring protected
3	Water treated
Cooking Fuel	Main source of cooking fuel
0	Collected firewood, grass, battery/dry cell (torch), candles, other
1	Purchased firewood, coal, kerosene, electricity, gas
Radio	Access to a radio
0	No
1	Yes
TV	Access to a television
0	No
1	Yes
Cell Phone	Access to a mobile phone
0	No
1	Yes
Computer	Access to a computer
0	No
1	Yes
Internet	Access to the internet
0	No
1	Yes

Table 5. Definitions of the Wellbeing Index components

Wellbeing Index	
Variables	Definition
Walls	The material predominantly used for the outer walls of the main dwelling
Floor	The material predominantly used for the floor of the main dwelling
Roof	The material predominantly used for the roof of the main dwelling
Electricity	Electricity working in the dwelling (yes=1; else=0)
Bathroom	Kind of toilet facility used by the household
Rooms	Number of separate rooms occupied by household members (accept bathrooms, toilets, storerooms, or garage)
Property	Type of property (own, rented, free or not)
Water source	Main source of drinking water in the household
Cooking Fuel	Main source of fuel used for cooking
Radio	Household has access to radio (yes=1; else=0)
TV	Household has access to TV set (yes=1; else=0)
Cell phone	Household has access to cell phone (yes=1; else=0)
Computer	Household has access to computer (yes=1; else=0)
Internet	Household has access to internet (yes=1; else=0)

Table 6. Calculating the index for the household 10001

Variable	**Category Value**	**Score**	**Normalized score (0 - 100)**
Walls	Concrete	3	(3/3)*100 = 100
Floor	Smooth cement	1	(1/1)*100 = 100
Roof	Other	0	(0/2)*100 = 0
Electricity	Yes	1	(1/1)*100 = 100
Bathroom	Flush to septic tank	2	(2/2)*100 = 100
Rooms	6	4	(4/4)*100 = 100
Property	Owned	2	(2/2)*100 = 100
Water source	Hang pump	2	(2/3)*100 = 66.67
Cooking Fuel	Kerosene	1	(1/1)*100 = 100
Radio	Yes	1	(1/1)*100 = 100
TV	Yes	1	(1/1)*100 = 100
Cell phone	Yes	1	(1/1)*100 = 100
Computer	Yes	1	(1/1)*100 = 100
Internet	Yes	1	(1/1)*100 = 100

Table 7. Definitions of the dependent and explanatory variables related to the models

Variables	Definition
Dependent	
Tomato_b	Household consumed tomato during past 7 days (yes=1; else = 0)
Onion_b	Household consumed onion during past 7 days (yes=1; else = 0)
Pepper_b	Household consumed pepper during past 7 days (yes=1; else = 0)
Okrafresh_b	Household consumed fresh okra during past 7 days (yes=1; else = 0)
W_tomato	Expenditure share of the household spent on tomato
W_onion	Expenditure share of the household spent on onion
W_pepper	Expenditure share of the household spent on pepper
W_okrafresh	Expenditure share of the household spent on fresh okra
Explanatory	
Geographical Location	
NC	Household located in the North-Central region (yes=1; else = 0)
NE	Household located in the North-Eastern region (yes=1; else = 0)
NW	Household located in the North-Western region (yes=1; else = 0)
SE	Household located in the South-Eastern region (yes=1; else = 0)
SS	Household located in the South-Southern region (yes=1; else = 0)
SW[a]	Household located in the South-Western region (yes=1; else = 0)
Sector	Household located in the sector (urban=1; rural=0)
Lga	Local Governmental Area ()
Ea	Enumeration area ()
State	36 states and the Federal Capital Territory, Abuja
Ric	Replicate Identification Code, four digit code
Demographic characteristics	
Newhhid	Household head (male=1; female=0)
Religion	Islam=1; else (Christian, traditional, other) =0
Marriage	Household head marital status (married (monogamous or polygamous), or union = 1; else (single, widowed, separated, never married) =0)
Giftfood	Household receives food as a gift (yes=1; else=0)
Ownfood	Household produces food for own consumption (yes=1; else=0)

Table 7. Continued

Variables	Definition
Demographic characteristics	
Agact	Household head primary activity is in agricultural sector (yes=1; else (mining, manufacturing, professional/ scientific/technical activities, electricity/water/ gas/waste, construction, transportation, buying and selling, financial/insurance/ real est. services, personal services, education, health, public administration, other) =0)
Wage	Household head receives a wage (yes=1; else=0)
Headage	Age of the household head
Hhsize	Number of people in the household
Wellbeingindex	Index ranges from 0 to 100
Young20	Fraction of the household members of age between 0 to 20 years old
Middle40	Fraction of the household members of age between 21 to 40 years old
Senior60[a]	Fraction of the household members of age between 41 to 60 years old
Elderly	Fraction of the household members who are over 60 years old
Expenditure and prices	
X_new	Total household expenditure for tomato, onion, peppers and fresh okra
Lxp	The linear price index for the LA/AIDS model
Lpon	Logarithm of normalized price of onion
Lpp	Logarithm of normalized price of peppers
Lpok	Logarithm of normalized price of fresh okra
Lpt	Logarithm of normalized price of tomato

Source: Nigeria General Household Survey (GHS)

[a] Reference categories excluded from the Probit model regressions.

Table 8. Distribution of the final sample data by Geographic Location

Zone	State	Total			Urban		Rural	
		LGA[a]	EAs[b]	Hhs[c]	EAs[b]	Hhs[c]	EAs[b]	Hhs[c]
North-Central	Benue	14	16	105	2	16	14	89
	Kogi	9	12	81	4	25	8	56
	Kwara	10	12	91	6	48	6	43
	Nasarawa	7	7	57	1	7	6	50
	Niger	13	18	122	4	33	14	89
	Plateau	10	11	87	2	14	9	73
	FCT Abuja	2	4	24	3	15	1	9
Sub-total				567		158		409
Sub-Total (%)[d]				18.69		5.21		13.48
North-East	Adamawa	12	12	86	1	5	11	81
	Bauchi	12	17	147	3	22	14	125
	Borno	17	21	149	5	35	16	114
	Gombe	7	8	55	2	16	6	39
	Taraba	8	9	69	0	0	9	69
	Yobe	10	13	83	3	20	10	63
Sub-total				589		98		491
Sub-Total (%)[d]				19.42		3.23		16.19
North-West	Jigawa	12	13	89	2	17	11	72
	Kaduna	12	12	80	4	24	8	56
	Kano	19	19	167	3	25	16	142
	Katsina	16	18	143	3	19	15	124
	Kebbi	8	10	82	1	8	9	74
	Sokoto	8	8	51	2	12	6	39
	Zamfara	9	9	53	2	13	7	40
Sub-total				665		118		547
Sub-Total (%)[d]				21.93		3.89		18.03
South-East	Abia	10	11	66	4	28	7	38
	Anambra	9	11	24	5	10	6	14
	Ebonyi	9	11	31	1	3	10	28
	Enugu	9	10	19	1	1	9	18
	Imo	17	19	88	2	9	17	79
Sub-total				228		51		177
Sub-Total (%)[d]				7.52		1.68		5.84
South-South	Akwa-Ibom	13	15	77	4	19	11	58
	Bayelsa	6	7	15	1	1	6	14
	Cross River	13	13	86	3	19	10	67
	Delta	11	14	88	4	21	10	67
	Edo	8	10	68	5	25	5	43
	Rivers	17	21	121	7	36	14	85
Sub-total				455		121		334
Sub-Total (%)[d]				15.00		3.99		11.01
South-West	Ekiti	7	8	51	6	39	2	12

Table 8. Continued

Zone	State	Total			Urban		Rural	
		LGA[a]	EAs[b]	Hhs[c]	EAs[b]	Hhs[c]	EAs[b]	Hhs[c]
South-West	Lagos	13	17	109	16	101	1	8
	Ogun	9	11	61	7	39	4	22
	Ondo	10	13	72	6	34	7	38
	Osun	11	18	88	14	61	4	27
	Oyo	18	23	148	15	93	8	55
Sub-total				529		367		162
Sub-Total (%)[d]				17.44		12.10		5.34
Total		405	481	3,033	154	913	327	2,120
Total (%)[d]				100.00		30.10		69.90

Source: Nigeria General Household Survey
[a] A number of Local Governmental Areas in the sample
[b] A number of Enumeration Areas in the sample
[c] A number of households in every geographic zones
[d] A percentage of present households in the zone when compared to national level

Table 9. Sample statistics of expenditures, quantities, prices and expenditure shares, N = 3033 households

Variables	% Consuming households	Mean	S.D.
Expenditures[a] (Naira/week/per hh)			
Onion	80.28	102.38	145.02
Peppers	67.92	127.40	173.90
Okra – fresh	28.55	80.66	69.29
Tomato	66.70	142.50	109.26
Other-vegetables	64.59	219.62	317.50
Quantities[b] (kg/per household)			
Onion		1.02	2.15
Peppers		0.89	1.98
Okra – fresh		0.76	0.88
Tomato		2.19	2.67
Other-vegetables		4.56	6.54
Prices[c] (Naira/kg)			
Onion		161.57	87.87
Peppers		399.67	369.64
Okra – fresh		130.00	56.01
Tomato		83.07	34.68
Other-vegetables		45.23	23.82
Expenditure shares[d]			
Onion		0.24	0.25
Peppers		0.20	0.23
Okra – fresh		0.06	0.14
Tomato		0.23	0.23
Other-vegetables		0.27	0.33

Note: [a] Means of household expenditures were calculated using reported quantities and prices, none of the observations where market price was inputted was considered
[b] Means of quantities were calculated excluding zero observations
[c] Means of prices are calculated on national level, not taking into consideration any inserted mean prices
[d] Means of expenditure shares were calculated including zero observations, otherwise the shares would not sum to unity.

Table 10. Diagnostics of Multicollinearity in first stage: Probit models[a]

	Onion	Peppers	Okra	Tomato
Variables	VIF			
Newhhid	2.43	2.43	2.43	2.43
Marriage	2.51	2.51	2.51	2.51
Religion	1.92	1.92	1.92	1.92
Headage	2.54	2.54	2.54	2.54
Giftfood	1.05	1.05	1.05	1.05
Ownfood	1.74	1.74	1.74	1.74
NC	2.07	2.07	2.07	2.07
NE	2.62	2.62	2.62	2.62
NW	2.86	2.86	2.86	2.86
SE	1.55	1.55	1.55	1.55
SS	1.92	1.92	1.92	1.92
Sector	1.75	1.75	1.75	1.75
School	1.44	1.44	1.44	1.44
Agact	2.04	2.04	2.04	2.04
Wage	1.39	1.39	1.39	1.39
Wellbeingindex	2.06	2.06	2.06	2.06
Hhsize	2.19	2.19	2.19	2.19
Young20	3.40	3.40	3.40	3.40
Middle40	2.41	2.41	2.41	2.41
Elderly	2.08	2.08	2.08	2.08
X_new	1.25	1.25	1.25	1.25
Mean	2.06	2.06	2.06	2.06

Note: [a] The definition of the variables is in Table 8

Table 11. Diagnostics of Multicollinearity in second stage: SUR[a]

	Onion	Peppers	Okra	Tomato
Variables	VIF			
lpon	1.39	1.42	1.38	1.42
lpp	1.57	1.51	1.51	1.53
lpok	1.68	1.72	1.72	1.69
lpt	1.25	1.25	1.25	1.25
lpoth	1.16	1.15	1.15	1.17
lxp	1.57	1.44	1.26	1.27
PDF_i	1.44	1.35	1.14	1.15
Mean	1.44	1.41	1.34	1.35

Note: [a] The definition of the variables is in Table 8

Table 12. Maximum Likelihood Estimates of Probit Models

	Onion		Peppers		Okra		Tomato	
Parameter	β_{onion}	Std	β_{pepper}	Std	$\beta_{okrafresh}$	Std	β_{tomato}	Std
Intercept	0.0303	0.2920	0.8844***	0.2762	-1.2167***	0.2831	-0.8013***	0.2855
		[0.2966]		[0.2739]		[0.2899]		[0.2828]
Newhhid	-0.3719***	0.1309	-0.3574***	0.1241	-0.1659	0.1222	-0.3039**	0.1261
		[0.1354]		[0.1218]		[0.1255]		[0.1340]
Marriage	0.1953*	0.1124	0.1959*	0.1079	0.2585**	0.1102	0.1263	0.1112
		[0.1195]		[0.1103]		[0.1108]		[0.1176]
Religion	-0.2129***	0.0737	-0.0731	0.0681	0.0579	0.0686	0.2269***	0.0710
		[0.0760]		[0.0694]		[0.0679]		[0.0729]
Headage	0.0006	0.0029	-0.0005	0.0027	-0.0037	0.0028	0.0047*	0.0028
		[0.0030]		[0.0028]		[0.0028]		[0.0028]
Giftfood	-0.0774	0.0833	-0.2075***	0.0772	-0.1150	0.0810	-0.1417*	0.0808
		[0.0849]		[0.0815]		[0.0813]		[0.0869]
Ownfood	0.1618**	0.0701	-0.0002	0.0647	0.1807***	0.0669	0.1444**	0.0677
		[0.0708]		[0.0648]		[0.0665]		[0.0691]
NC	-0.0728	0.0982	-0.4751***	0.0934	0.4204***	0.0905	-0.7931***	0.0989
		[0.0998]		[0.0943]		[0.0934]		[0.0983]
NE	-0.0343	0.1079	-0.4404***	0.1023	0.1984*	0.1018	-0.6306***	0.1085
		[0.1084]		[0.1025]		[0.1067]		[0.1101]
NW	-0.0014	0.1081	-0.2832***	0.1037	-0.1537	0.1039	-0.0315	0.1141
		[0.1092]		[0.1051]		[0.1064]		[0.1121]
SE	-0.1995	0.1258	-0.1624	0.1206	0.2911**	0.1161	-0.4493***	0.1232
		[0.1260]		[0.1245]		[0.1211]		[0.1249]
SS	-0.1961*	0.1051	-0.5674***	0.0986	0.4909***	0.0949	-1.3970***	0.1032
		[0.1103]		[0.0999]		[0.0975]		[0.1115]
Sector	-0.0532	0.0773	0.1240*	0.0715	0.1346*	0.0702	0.1948***	0.0745

Table 12. Continued

	Onion		Peppers		Okra		Tomato	
Parameter	β_{onion}	Std	β_{pepper}	Std	$\beta_{okrafresh}$	Std	β_{tomato}	Std
		[0.0780]		[0.0743]		[0.0734]		[0.0756]
School	0.0016	0.0666	0.0521	0.0612	-0.0910	0.0643	0.2641***	0.0641
		[0.0671]		[0.0621]		[0.0659]		[0.0643]
Agact	0.0684	0.0766	-0.1642**	0.0702	-0.0817	0.0711	-0.0706	0.0732
		[0.0758]		[0.0721]		[0.0714]		[0.0762]
Wage	0.0499	0.0627	-0.0070	0.0578	0.1391**	0.0582	-0.0933	0.0606
		[0.0634]		[0.0586]		[0.0595]		[0.0632]
Wellbeing	0.0087***	0.0027	-0.0030	0.0025	0.0047*	0.0026	0.0180***	0.0026
		[0.0028]		[0.0025]		[0.0027]		[0.0027]
Hhsize	-0.0159	0.0126	-0.0253**	0.0115	-0.0362***	0.0119	-0.0289**	0.0121
		[0.0128]		[0.0119]		[0.0123]		[0.0125]
Young20	0.4392**	0.1956	0.2340	0.1850	0.2432	0.1886	0.3629*	0.1917
		[0.1931]		[0.1817]		[0.1945]		[0.1930]
Middle40	0.3526**	0.1753	0.2827*	0.1667	-0.1158	0.1715	-0.0803	0.1718
		[0.1702]		[0.1675]		[0.1752]		[0.1648]
Elderly	0.0848	0.1878	0.4157**	0.1861	-0.0360	0.1883	-0.0336	0.1872
		[0.1906]		[0.1909]		[0.1940]		[0.1999]
X_new	<0.001***	0.0001	<0.001***	0.0001	<0.001***	0.0001	<0.001***	0.0001
		[0.0001]		[0.0002]		[0.0001]		[0.0002]
Model Fit Statistics								
-2*log likelihood (intercept)		3011.44		3806.26		3628.06		3859.71
-2*log likelihood (intercept and covariates)		2909.89		3547.63		3411.57		3195.05
Log Likelihood[a]		-1454.95		-1773.81		-1705.78		-1597.52
LR Chi-Sq		101.55		258.63		216.49		664.66

Table 12. Continued

	Onion	Peppers	Okra	Tomato
Model Fit Statistics				
Pr>Chi-Sq	<0.0001	<0.0001	<0.0001	<0.0001
Pseudo R^{2b}	0.0337	0.0679	0.0597	0.1722
Degrees of Freedom	21	21	21	21
Correctly classified	80.32%	69.60%	71.55%	73.06%

Note: The standard errors using bootstrap procedure are recorded in [brackets]. *** ($p < 0.01$), ** ($p < 0.05$) and * ($p < 0.1$)

[a] *Log likelihood*= -2*log likelihood (intercept and covariates)/(-2).
Onion: -1454.95 = 2909.89/(-2)
Peppers: -1773.81 = 3547.63/(-2)
Okra: -1705.78 = 3411.57/(-2)
Tomato: -1597.52 = 3195.05/(-2)

[b] McFadden's *Pseudo* R^2 = 1 – (-2*log likelihood (intercept and covariates)/ -2*log likelihood (intercept)).
Onion: .0337 = 1 - (2909.89/3011.44)
Peppers: .0679 = 1 - (3547.63/3806.26)
Okra: .0597 = 1 - (3411.57/3628.06)
Tomato: .1722 = 1 - (3195.05/3859.71)

Table 13. The estimated parameters of the LA/AIDS model[a]

Parameter	Onion	Peppers	Okra	Tomato
α_I	0.9924***	0.2645***	-0.1299***	0.0618*
	(0.0399)	(0.0452)	(0.0170)	(0.0356)
	[0.0763]	[0.0973]	[0.0203]	[0.0528]
β_I	-0.1130***	0.0080	-0.0160***	0.0367***
	(0.0057)	(0.0063)	(0.0030)	(0.0053)
	[0.0098]	[0.0116]	[0.0032]	[0.0064]
γ_{i1}	-0.0221**			
	(0.0089)			
	[0.0108]			
γ_{i2}	-0.0129***	0.0509***		
	(0.0047)	(0.0055)		
	[0.0049]	[0.0061]		
γ_{i3}	0.0046	0.0028	0.0008	
	(0.0058)	(0.0034)	(0.0083)	
	[0.0051]	[0.0029]	[0.0076]	
γ_{i4}	0.0203***	-0.0083*	0.0087*	0.0749***
	(0.0071)	(0.0050)	(0.0061)	(0.0101)
	[0.0083]	[0.0052]	[0.0050]	[0.0102]
δ_I	0.0950***	0.0801***	0.5919***	0.1337***
	(0.0343)	(0.0274)	(0.0166)	(0.0229)
	[0.0712]	[0.0602]	[0.0467]	[0.0382]
R^2	0.266	0.162	0.222	0.164
Adjusted R^2	0.265	0.161	0.221	0.163
Heteroscedasticity Test				
Breusch-Pagan Test	304.20	99.00	49.77	132.30
Pr > χ^2	<0.0001	<0.0001	<0.0001	<0.0001

Note: *** the asterisk indicates that the estimated coefficient is statistically significant at 1.0%, (p < 0.01)
** significant at the 5.0%, (p < 0.05) and * Significant at the 10.0%, (p < 0.1)

[a] Standard errors are reported in round parentheses below the estimates. The adjusted standard errors using bootstrap procedure are reported below original standard errors in parentheses [brackets]

Table 14. The results of Likelihood Ratio test

Joint restriction	Statistics	Pr > χ^2
$\gamma_{onoth} = 0 - \gamma_{onon} - \gamma_{onp} - \gamma_{onok} - \gamma_{ont}$ $\gamma_{poth} = 0 - \gamma_{onp} - \gamma_{pp} - \gamma_{pok} - \gamma_{pt}$ $\gamma_{okoth} = 0 - \gamma_{onok} - \gamma_{pok} - \gamma_{okok} - \gamma_{okt}$ $\gamma_{toth} = 0 - \gamma_{ont} - \gamma_{pt} - \gamma_{okt} - \gamma_{tt}$	692.66	<0.0001

Table 15. Uncompensated (Marshallian) Price and Expenditure Elasticities[a]

Uncompensated (Marshallian) Price Elasticities of Demand System					Expenditure Elasticity
	Onion	Peppers	Okra	Tomato	
Onion	-0.986***	0.032**	0.035**	0.140***	0.672***
	(0.032)	(0.014)	(0.016)	(0.031)	(0.045)
	[-1.045]^{l}	[0.007]^{l}	[0.014]^{l}	[0.097]^{l}	[0.606]^{l}
	[-0.939]^{u}	[0.053]^{u}	[0.064]^{u}	[0.186]^{u}	[0.727]^{u}
Peppers	-0.045***	-0.852***	0.007▲	-0.121▲	1.024***
	(0.017)	(0.021)	(0.009)	(4.17)	(0.037)
	[-0.075]^{l}	[-0.884]^{l}	[-0.007]^{l}	[-0.276]^{l}	[0.972]^{l}
	[-0.019]^{u}	[-0.819]^{u}	[0.023]^{u}	[0.081]^{u}	[1.089]^{u}
Okra	0.927	0.591	-0.912	1.225	-0.639▲
	(47.283)	(64.013)	(48.380)	(87.167)	(66.980)
	[0.064]^{l}	[0.059]^{l}	[-1.760]^{l}	[0.160]^{l}	[-1.463]^{l}
	[1.618]^{u}	[0.901]^{u}	[-0.470]^{u}	[1.944]^{u}	[0.690]^{u}
Tomato	0.030▲	-0.013▲	0.020▲	-0.794***	1.113***
	(0.034)	(0.018)	(0.028)	(0.206)	(0.102)
	[-0.013]^{l}	[-0.030]^{l}	[-0.004]^{l}	[-0.852]^{l}	[1.079]^{l}
	[0.073]^{u}	[0.003]^{u}	[0.048]^{u}	[-0.724]^{u}	[1.155]^{u}

Note: *** the asterisk indicates that the estimated coefficient is statistically significant at 1.0%, ($p < 0.01$)
** significant at the 5.0%, ($p < 0.05$) and * Significant at the 10.0%, ($p < 0.1$)
Standard errors estimated using Bootstrap procedure are reported in round parentheses below the elasticity estimates.
Values in brackets are lower(^{l} – 5) and upper (^{u} – 95) percentiles. A triangle (▲) indicates that the 90.0% interval includes zero.

Table 16. Compensated (Hicksian) Price Elasticities[a]

Compensated (Hicksian) Price Elasticities of Demand System				
	Onion	Peppers	Okra	Tomato
Onion	-0.811***	0.165***	0.075***	0.290***
	(0.033)	(0.015)	(0.016)	(0.025)
	[-0.870][l]	[0.139][l]	[0.054][l]	[0.251][l]
	[-0.763][u]	[0.189][u]	[0.104][u]	[0.332][u]
Peppers	0.214***	-0.644***	0.070***	0.206***
	(0.016)	(0.021)	(0.009)	(0.017)
	[0.188][l]	[-0.676][l]	[0.055][l]	[0.179][l]
	[0.240][u]	[-0.609][u]	[0.087][u]	[0.234][u]
Okra	0.729	0.496	-0.837	1.122
	(25.289)	(46.332)	(48.380)	(75.007)
	[0.166][l]	[0.135][l]	[-1.689][l]	[0.266][l]
	[1.369][u]	[0.758][u]	[-0.393][u]	[1.719][u]
Tomato	0.315***	0.177***	0.088**	-0.539***
	(0.053)	(0.024)	(0.037)	(0.206)
	[0.272][l]	[0.149][l]	[0.063][l]	[-0.595][l]
	[0.361][u]	[0.206][u]	[0.117][u]	[-0.473][u]

Note: *** the asterisk indicates that the estimated coefficient is statistically significant at 1.0%, ($p < 0.01$)
** significant at the 5.0%, ($p < 0.05$) and * Significant at the 10.0%, ($p < 0.1$)
Standard errors estimated using Bootstrap procedure are reported in round parentheses below the elasticity estimates.
Values in brackets are lower([l] – 5) and upper ([u] – 95) percentiles.

Table 17. Marginal effects at variables means. Results from Probit models

Onion		Peppers		Okra		Tomato	
Var^a	$M.E.^b$	Var^a	$M.E.^b$	Var^a	$M.E.^b$	Var^a	$M.E.^b$
Newhhid	-0.088***	*Newhhid*	-0.116***	*Newhhid*	-0.057	*Newhhid*	-0.098***
Marriage	0.056*	*Marriage*	0.071*	*Marriage*	0.081**	*Marriage*	0.045
Religion	-0.057***	*Religion*	-0.026	*Religion*	0.019	*Religion*	0.079***
Headage	<0.001	*Headage*	<0.001	*Headage*	-0.001	*Headage*	0.002
Giftfood	-0.021	*Giftfood*	-0.076***	*Giftfood*	-0.037	*Giftfood*	-0.050*
Ownfood	0.044**	*Ownfood*	<0.001	*Ownfood*	0.060***	*Ownfood*	0.050**
NC	-0.020	*NC*	-0.176***	*NC*	0.149***	*NC*	-0.297***
NE	-0.009	*NE*	-0.163***	*NE*	0.068*	*NE*	-0.234***
NW	<0.001	*NW*	-0.103***	*NW*	-0.050	*NW*	-0.011
SE	-0.058	*SE*	-0.059	*SE*	0.103**	*SE*	-0.168***
SS	-0.056*	*SS*	-0.213***	*SS*	0.177***	*SS*	-0.515***
Sector	-0.014	*Sector*	0.043*	*Sector*	0.045*	*Sector*	0.066***
School	<0.001	*School*	0.018	*School*	-0.031	*School*	0.093***
Agact	0.019	*Agact*	-0.057**	*Agact*	-0.027	*Agact*	-0.024
Wage	0.013	*Wage*	-0.002	*Wage*	0.046**	*Wage*	-0.032
Wellbeing	0.002***	*Wellbeing*	-0.001	*Wellbeing*	0.002*	*Wellbeing*	0.006***
Hhsize	-0.004	*Hhsize*	-0.009**	*Hhsize*	-0.012***	*Hhsize*	-0.010**
Young20	0.119**	*Young20*	0.082	*Young20*	0.081	*Young20*	0.126*
Middle40	0.095**	*Middle40*	0.099*	*Middle40*	-0.039	*Middle40*	-0.028
Elderly	0.023	*Elderly*	0.146**	*Elderly*	-0.012	*Elderly*	-0.012
X_new	<0.001***	*X_new*	<0.001***	*X_new*	<0.001***	*X_new*	<0.001***

Note: [a] Var stands for variables. The definition of the variables is in Table 8
[b] Marginal effects (M.E.) represent approximation to the household's change in vegetables (onion, peppers, fresh okra and tomato) purchasing decisions for a unit change in continuous and discrete variables.
* Significant at the 10.0%, (p < 0.10)
** Significant at the 5.0%, (p < 0.05)
*** Significant at the 1.0%, (p < 0.01)

APPENDIX D: List of figures

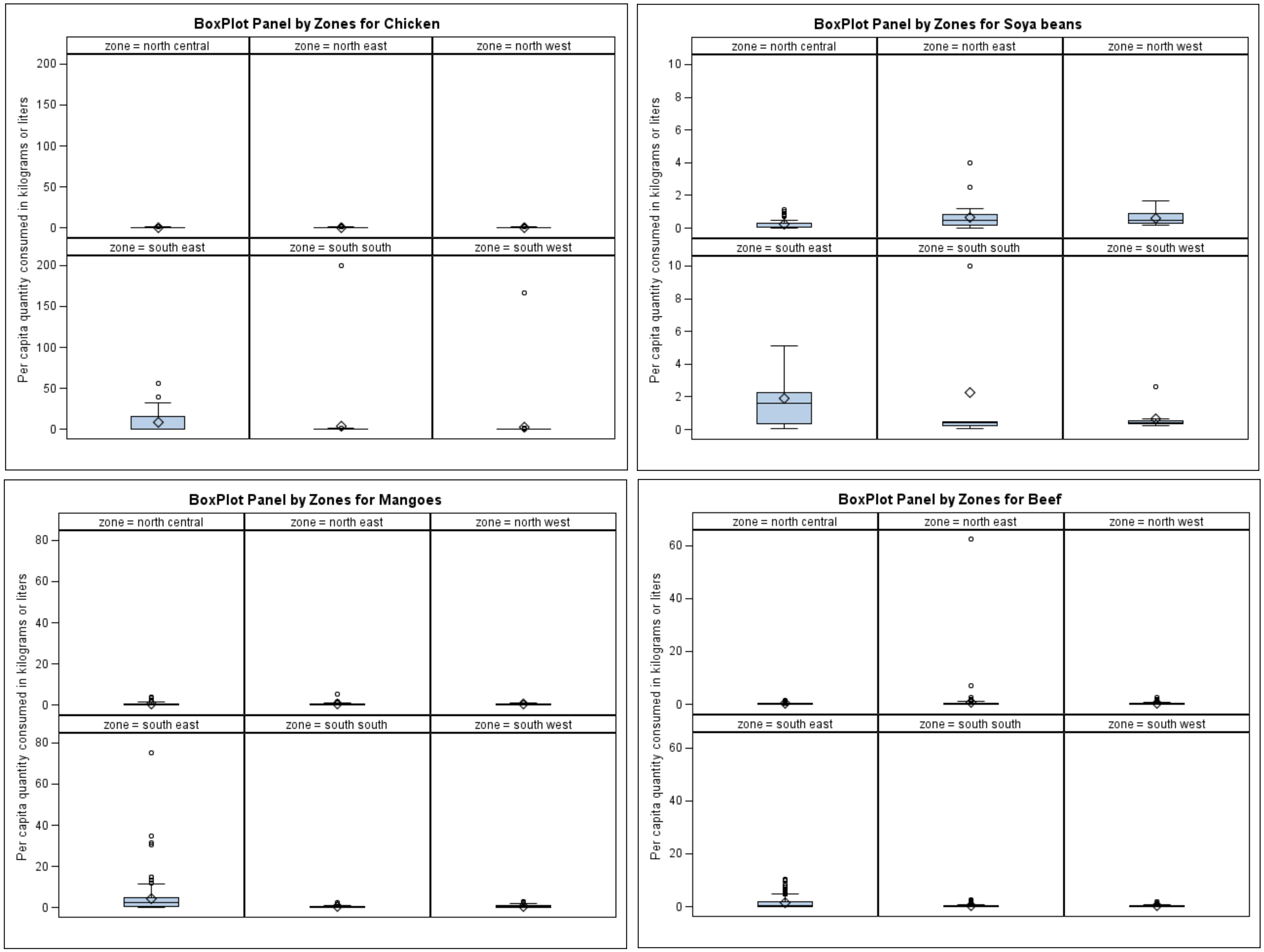

Figure 1. Graphical representation of per capita quantities consumed of different products in different geographic regions of Nigeria

VITA

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