BAHIR DAR UNIVERSITY

ADOPTION OF IMPROVED POTATO VARIETIES AND ITS IMPACT ON HOUSEHOLD NUTRITION: EVIDENCE FROM EMBA ALAJE WOREDA, NORTHERN ETHIOPIA.

M.Sc Thesis

By

MOHAMMED EBRAHIM

JUNE, 2019

COLLEGE OF AGRICULTURE AND ENVIRNOMENTAL SCIENCE

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ADOPTION OF IMPROVED POTATO VARIETIES AND ITS IMPACT ON HOUSEHOLD NUTRITION: EVIDENCE FROM EMBA ALAJE WOREDA, NORTHERN ETHIOPIA.

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BY

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THESIS APPROVAL SHEET

As member of the Board of Examiners of the Master of Sciences (M.Sc.) thesis open defense examination, we have read and evaluated this thesis prepared by Mr Mohammed Ebrahim entitled **"*Adoption of Improved Potato Varieties and Its Impact on Household Nutrition: Evidence from Emba Alaje woreda, Northern Ethiopia*".** We hereby certify that; the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Sciences (M.Sc.) in Agricultural Economics.

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DECLARATION

This is to certify that this thesis entitled with **"*Adoption of Improved Potato Varieties and Its Impact on Household Nutrition: Evidence from Emba Alaje woreda, Northern Ethiopia*".** Submitted in partial fulfillment of the requirements for the award of Master of Science in agricultural economics to the Graduate Program College of Agriculture and Environmental Sciences, Bahir Dar University by Mr. Mohammed Ebrahim who is an authentic work carried out by himself under our guidance. The matter embodied in this project work has not been submitted earlier for award of any degree or diploma to the best of our knowledge and belief.

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ABSTRACT

High population pressure and continuous decrease of the land holding size results in increase of food insecurity. To meet the increasing food demand of the growing population there is a need to intensify production practices. In this regard, improved potato varieties production plays a great role in improving the household's food security, food consumption, and food diversity, and there-by contributing to nutrition security. This study analyzes the probability and use intensity of improved potato varieties adoption and, the effect of adoption on households' nutrition security. The data was collected in 2018 at Emba Alaje *woreda* from a survey of 370 households (185 improved potato variety growers and 185 non-growers). Sampling weights were used to account the proportion of the sample compared to the whole population. Tobit model was used to analyze the factors affecting the probability and use intensity of improved potato varieties adoption. Both propensity score matching (PSM) and endogenous switching regression model (ESRM) were used to analyze the impacts of improved potato varieties on households' nutrition using Food security scale, Food consumption score and Household dietary diversity score proxy variables. To control the possible selection problem invers mill's ratio was included in the second stage equations. Size of own land, distance of the nearest plot, access to extension services, the existence of neighbor adopter, perception on the improved potato varieties' maturity period and tuber yield potential were found as the main factors of adoption probability and use intensity of improved potato varieties. The PSM result indicated that, adoption of improved potato varieties increases the average food security scale, food consumption score and the dietary diversity score by 1.79, 6.6 and 0.8 points, respectively. Similarly, the ESRM result confirmed that, improved potato varieties adoption increases the average food security scale, food consumption and dietary diversity score by 2, 6.1 and 1.4 points, respectively. Thus, to improve the nutritional status of the farming households, government should give due emphasis for potato production and the extension service need to be strengthen.

Keywords: Improved potato variety, Adoption, Nutrition security, Endogenous switching regression model, Propensity score matching, Tobit model, Northern Ethiopia.

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LIST OF ABBREVIATION

ADB	African Development Bank
ATE	Average Treatment Effect
ATT	Average Treatment Effect of the Treated
ATU	Average Treatment Effect of Untreated
CAADP	Comprehensive Africa Agriculture Development Programme
CFS	Committee on World Food Security
CIP	International Potato Center
CSA	Central Statistical Agency
EDHS	Ethiopian Demographic and Health Survey
ESR	Endogenous Switch regression Model
FAO	Food and Agricultural Organization
FCS	Food Consumption Score
FSS	Food Security Scale
FGD	Focused Group Discussion
GDP	Gross Domestic Product
GRAD	Graduation with Resilience to Achieve Sustainable Development
Ha	Hectare
HDDS	Household Dietary Diversity Score
IFPRI	International Food Policy Research Institute
ILRI	International Livestock Research Institute

LIST OF ABBREVIATION

IPV	Improved Potato Varieties
KM	Kilometer
NGO	Nongovernmental Organization
PSM	Propensity Score Matching Method
PSNP	Productive Safety Net Program
RISING	Research in Sustainable Intensification for the Next Generation
SPSS	Statistical Package for Social Science
VAM	Vulnerability Analysis and Mapping

1. INTRODUCTION

1.1. Background and Justification

The cultivated potato (Solanum tuberosum L.) originated in South America where it has been used for food for over 10,000 years (CDC, 1999a) and globally, potato is a crop of world's major economic importance and number one non-grain food commodity (Rykaczewska, 2013). It is the third most important food crop in terms of consumption after rice and wheat (Hielke *et al*., 2011; Birch *et al.*, 2012; Hancock *et al.*, 2014). Potato cultivation is exceeding 18.6 million hectares of land in more than 157 countries in the world with an estimated annual production of 330 million tons (Singh, 2008; FAO, 2009, 2010).

According to FAO (2008) potato is a good source of income, and employment opportunity in developing countries and it is a good source of dietary energy and some micronutrients, and its protein content is very high in comparison with other roots and tubers. Due to its correct balance between protein and calories, it is considered as a good weaning food and these traits make it an efficient crop in combating world hunger and malnutrition (Berga *et al*., 1994). The commercial value of potatoes has increased considerably when it is processed into edible products (Kirkman, 2007). Potato consumption has increased in the developing world, and over the last decade world potato production has increased at an annual average rate of 4.5 percent Furthermore; Kirkman (2007) has estimated that global consumption in its processed form will increase from 13% of total food use in 2002 to nearly 18% by 2020.

According to Mazengia (2016) potato has multiple benefits for low-income households where the land shortage is a constraint. It grows quickly, has a high yield, and contains more energy and protein per unit area when compared to cereal crops. Therefore, Potato can provide nutritious food for the poor and hungry in the developing countries and it is the most important crop to address food and nutrition security (Hussain, 2016), which is a major concern for countries like Ethiopia. High potato yield at critical food shortage periods could help households to get cash from the sale of potato and spend on a diversity of food types Mugisha *et.al*. (2017). Thus, potato production could increase the food availability and diversity. According to (FAO, 2008), potato has been declared as a Future Food crop and the

United Nation during the international potato year (2008), call the crop a “hidden treasure” (Hussain, 2016).

In Ethiopia, potato has been cultivated for over 150 years (Kolech *et al*., 2015); currently it is grown in many parts of the country. The production area has reached 59,504 ha cultivated by over one million households in the main cropping season of 2011 (CSA, 2012). There is a high potential to expand the cultivation area of the potato crop, as most arable land is in principle suitable for cropping potato.

Joshi, *et al*. (2009) indicated that the potential yield of potato in Ethiopia can reach up to 50 t/ha, but the average national potato production is 10.5 tones/ha, while progressive farmers who use improved agronomic practice attained yields of 25 tones/ha. According to CIP and ILRI (2016), improved potato varieties and with improved agronomic practice provided better tuber yields; Belete, Jalene, Gudene, and Gera varieties provide 46.93, 40.01, 38.93, and 32.98 tones of tuber yield per hectare respectively while the local variety provides only 14.4 t/ha. The results of the partial budget analysis also revealed that the use of improved potato varieties with its packages resulted in the net benefit of 122,535 birr/ha compared to the use of local variety and practice 43,920 birr/ha.

The production problems that account for low yields and tuber quality are similar to the problems that were identified in many developing countries including Ethiopia. Limited supply of high-quality seed tubers (Gildemacher *et al*., 2009), inappropriate agronomic practices and inadequate storage (Tekalign, 2005), poor knowledge of seed tubers selection (Adane *et al*,.2010) are reported as much contributing factors to the low yields and poor-quality seed tubers production. According to Berga and Woldegiorgis (1994), one of the major factors attributed to the low productivity of potato is limited access to improved varieties. The main constraints to access improved varieties are shortage of improved and quality seed, damaged and spoiled seed due to poor transporting and handling (Emana & Ngussie, 2011).

The available set of local varieties has been developed through a constant process of farmer experimentation, evaluation and selection of introduced varieties or clones from outside

sources. Varieties previously selected by farmers referred to as "local varieties"; while varieties developed by the research system over the past 28 years since their first release in 1987 referred to as "new varieties" (Kolech *et al*., 2015). Improved potato varieties are obtained through breeding process for disease resistance, drought tolerance, good yield, attractive color, size and shape, good cooking quality and other desirable characteristics (Asakaviciut *et al*., 2008).

In Tigray, the production of potato as food security crop and source of income has long a history. Starting 2013 the potato tuber seed multiplication and demonstration of new varieties both at seed producer cooperatives and model farmers' field was started in southern Tigray, particularly in Emba Alaje, Ofla and Endamehoni woreda supported by Government organization (Office of Agriculture) and different non-governmental organizations (NGOs) such as, Africa RISING, CIP (International Potato Center), and Graduation with Resilience to Achieve Sustainable Development (GRAD). However, the seed tubers and varieties promoted and delivered by these organizations were not sufficient for the areas due to the high increase of demand from farmers (Getachew, 2016).

Farmers in Emba Alaje *wereda* produced Gudene, Jalene and Belete potato varieties. These varieties provide different yields, varying from farmers to farmers. This is mainly because of the differences in adoption of potato production technology packages; recommended seed rate and seed size, spacing between plant and row, fertilizer rate, chemical application to control fungal disease and storage facilities (Getachew, 2016). Therefore, raising the efficiency among the growers is essential element for getting the desired return from the potato cultivation.

In Ethiopia few studies are conducted in SNNP, Oromia and Amhara region on adoption of potato varieties; ketema *et al*. (2016), Tesfay *et al*. (2006), and Endris (2003) studied the adoption rate and intensity of potato varieties, and other socio economics characteristics of farmers that affect the adoption of potato varieties and production packages. However, these studies did not address the impact of adoption of potato varieties on households' food security and nutrition. In Tigray region there was no adoption study carried out on potato and related production technologies. The adoption and intensity of use of improved potato varieties and

its impact on household nutrition were not analyzed well. Hence, this study investigated the demographic and socio-economic characteristics of farmers that influence the probability and level of adoption of improved potato varieties, and assess the impact of adoption of potatoes varieties on farm household nutrition in through household dietary diversity score, food consumption score and food security scale. Using this multiple food and nutrition security indicators, this study measures the quality, diversity and quantity aspects of households' food consumption.

1.2. Statement of the problem

Increasing population pressure, soil nutrient loss, land degradation, and shrinking land holdings necessitated intensification of production practices to meet the increasing food demand of the population. The agricultural sector suffers from poor cultivation practices and frequent drought. CAADP (2016) indicated that the Joint efforts by the Government of Ethiopia and donors have strengthened Ethiopia's agricultural resilience, contributing to a reduction in the number of Ethiopians threatened with starvation. However, the number of food insecure people in the country increases from time to time; estimated to 2.9 million in 2014 and 4.5 million in August, 2015 and by the end of the same year this figure had more than doubled to 10.2 million. Consequently, 27 million Ethiopian became food insecure as a result of 2015 El Niño drought and 18.1 million dependents on relief food assistance in 2016 (Abdulselam, 2017).

Under nutrition has long history and remains one of the major and most pressing health problem in Ethiopia. Nearly 40% of the rural farm family cultivate land less than half a hectare from where they produce only half of their annual food demand. Moreover, these farm family do not have enough purchasing power to buy from the market and children who have come from such a family member are almost malnourished (CAADP, 2016).

High yield potential, early mature, and drought and disease resistance improved crop varieties play a vital role to increase the food crop production in the changing environment. One of the greatest advantages of potato production is high productivity per unit of area. Potato is one of the most productive food crops in terms of yields of edible energy and good quality protein

per unit area and per unit of time fitting into, intensive cropping systems (Rizov *et al*., 2018). According to Joshi *et al*. (2009) Potato can yield maximum tuber yield 50 t/ha and compared to cereals it is short duration crop which can be harvested from 3-4 months (Endale *et al*., 2008b). In Emba Alaje potato reach for harvest at critical food shortage period, when the other food crops are finished from the storage and not matured in the field, usually at the end of September and October.

Emba Alaje is one the chronically food insecure *woreda* targeted by the Productive Safety Net Program (PSNP). The program started in 2005 with 23780 beneficiaries and currently number of PSNP beneficiaries raised to 30498. The figure shows an increase of 6718 beneficiaries. Thus, potato is a very important crop for the study areas where population pressure, food and nutrition insecurity are increasing. In addition, the study area has good climatic and edaphic conditions for higher potato production and productivity.

According to MOA (2012), in Ethiopia 29 improved potato varieties have released to enhance its productivity. However, in the highlands of Southern Tigray Zone, particularly in *Emba Alje* woreda only four improved potato varieties were introduced and promoted by government and non-governmental institutions in limited number of kebeles *kebeles*. Even though potato is a good pathway for enhancing food and nutrition security Mugisha *et.al*. (2017), in the study areas the adoption of the improved varieties is very low. No in-depth studies have been carried out on the factors and level of adoption of potato varieties and its impact on households' nutrition. Therefore, this study was to generate evidence on the major factor of the adoption and level of adoption of improved potato varieties, and its impact on households' nutrition.

1.3. Objectives of the Study

1.3.1 General objective

The overall objective of this study is to analyze the adoption of improved potato varieties and its impacts on smallholder farmers' nutrition in the study area.

1.3.2 Specific objectives

The specific objectives of the study are:

i. To identify socio-economic determinant factors that influence the probability and level of adoption of improved potato varieties
ii. To analyze the impact of improved potato varieties on households' nutrition by using food security scale (FSS), food consumption score (FCS), household diet diversity score (HDDS).

1.4 Research Questions

i. What are the socio-economic determinant factors that influence the probability and level of adoption of improved potato varieties by smallholder farmers?
ii. What are the impacts of improved potato varieties adoption on households' nutrition?

1.5. Significance of the Study

The findings of this study are expected to provide a comprehensive understanding on the level of adoption of improved potato varieties and farmers characteristics which determine the adoption of potato varieties and its' impacts on the farming household nutrition. The study findings could be used for policymaker, agricultural extension service providers, researchers, NGOs, farmers and potato seed producer cooperatives to design appropriate strategies and enhance the potential benefits from potato production and utilization. The results of this study would assist development activities underway and to be planned in the future in areas of potato. Extensions and other development practitioners would use the information to develop the appropriate extension agendas and to raise the awareness level of farmers on potato production and its role in food and nutrition security, employment and income generation. The results could be a basis for further investigation and setting of research agendas.

1.6. Scope and Limitation of the Study

The study was carried out by surveying a sample of randomly selected farm households from two *kebeles* (the lowest administration unit) of Emba Alaje *woreda* where the improved

potato varieties have been widely produced. Since improved potato grower farmers were few in number as compared to the non-producer groups and to increase the share of producer farmers an equal number of samples were selected randomly from both groups. There are seasonal differences in dietary patterns and for a more complete assessment of usual diet, dietary diversity should be measured in different seasons. Due to time and budget constraints, the study was limited geographically to one *woreda* and collected cross-sectional data. However, the results of the study are applicable to other areas with similar physical and socioeconomic settings.

2. REVIEW OF LITERATURE

In this chapter, the concept of adoption, food and nutrition security, dietary diversity and impact evaluation are explained. In addition, the past research works are critically reviewed in relevance to the present study objectives and the evidences from the reviews enables better understanding of the subject.

2.1. The Concept of Adoption

Adoption is defined as a decision to apply an innovation and to continue to use it over a reasonably long period of time (Ban and Hawkins, 1996) and according to Feeder *et al*. (1985) defined adoption as the degree of use of a new technology in a long run equilibrium when a farmer has all of the information about the new technology and its potential. Ban and Hawkin, (1985) further noted that adoption is not a permanent behavior. An individual may decide to discontinue the use of innovation for a variety of personal, institutional, or social reasons, one of which might be the availability of an idea or practice that is better in satisfying his/her need. Therefore, adoption at the farm level describes the realization of a farmer's decision to implement a new technology.

If innovations are modified periodically, however, the equilibrium level of adoption will not be achieved. This situation requires the use of econometric procedures that can capture both the rate and the process of adoption. As the new technology is introduced, some farmers will experiment with it before adopting.

The "rate of adoption" is defined as the proportion of farmers who have adopted a new technology at a specific point in time (e.g., the percentage of farmers using fertilizer). Nkony *et al*. (1997) also defined the rate of adoption as the level of adoption of a given technology. Furthermore, the "intensity of adoption" is defined as the level of adoption of a given technology, for example, by the number of hectares planted with improved seed or the amount of fertilizer applied per hectare (Degu, 2000). Markee (1992) defined adoption as the process of spreading of a new technology within a region, diffusion represents the cumulative process of adoption measured in successive times. Fliegel, (1984) noted that the rate of

diffusion depends, among other things, on extension communication and the extent to which farmers discuss agricultural issues among themselves routinely. According to Amit *et al*. (2017), the adoption process is the mental process through which an individual pass from first hearing of an innovation to its final adoption, while adoption is a decision to continue the full use of an innovation. Generally, the farmers do not adopt package of practices fully. There is only a partial adoption by them. As a result, the gap always appears between the recommended production technology and their use at the farmer's field.

2.2. The Concepts of Food and Nutrition Security

Food security is a concept that has evolved considerably over time and its definitions developed and diversified by different researchers, scholars and organizations (Abdulselam, 2017). Food security is a situation that achieved at the individual, household, national, regional and global levels when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 2008). Hussein (2013) defined food security as adequate availability of and access to food for households to meet the minimum energy requirements as recommended for an active and healthy life.

Micronutrient deficiencies in diets are widespread and have long-term consequences, reflected in a wide range of health outcomes, including stunting, cognitive abilities and non-communicable diseases. Yet, unlike insufficient energy intakes, which translate quickly into sensations of weakness and hunger, these deficiencies are not immediately apparent and are therefore often referred to as 'hidden' hunger (Kennedy *et al*., 2003). For the most food-insecure households, some of the most widespread deficiencies involve inadequate levels of vitamin A, iron and zinc, but many important micro- and macro-nutrients may be insufficiently (Lele *et al*., 2016).

2.2.1 Food Security Situation in Ethiopia

Ethiopia is facing a massive drought and food insecurity crisis over the years. According to ADB (2014), Ethiopia is one of the most food-insecure and famine affected countries. Drought, recurring food shortage and famine are great challenges faced by Ethiopian people.

A large portion of the country's population has been affected by chronic and transitory food insecurity. According to Care Ethiopia (2014) findings chronic and acute food insecurity are prevalent, especially among rural populations and smallholder farmers. The findings indicated that about 10 percent of Ethiopia's citizens are chronically food insecure, and this figure rises to more than 15 percent during frequent drought years. The El Nino -driven drought has greatly expanded food insecurity and malnutrition, and devastated livelihoods of the poorest and vulnerable people across the country (FAO, 2016).

Food Security and Hunger/ Undernourishment Multiple Indicator Scorecard indicated that, Ethiopia ranked as first in having the highest number of people in state of undernourishment/ hunger which is 32.1 million people. This makes it, the fourth African country scoring (37.1%) of the population being undernourished/ in hunger.

According to VAM (2008) there is no single way to measure food security, the concept itself being rather elusive. Food consumption measured in kilocalories is the gold standard for measuring consumption, and often considered to be one of the gold standards for food security. The food consumption score (FCS) as score which able to capture both Dietary Diversity and Food frequency.

2.2.2. Nutrition Security Situation in Ethiopia

The term of nutrition security emerged with the recognition of the necessity to include nutritional aspects into food security. Nutrition security as a condition when all people at all times consume food of sufficient quantity and quality in terms of variety, diversity, nutrient content and safety to meet their dietary needs and food preferences for an active and healthy life, coupled with a sanitary environment, adequate health and care (Belton and Thilsted, 2014) Ethiopia has shown some progress in reducing under nutrition in recent years. The EDHS (2011) indicated that nationally, 44% of children under the age of five are found to be stunted, 33% are underweight, and 12% are wasted (measures the more immediate effect of malnutrition). However, it is still a major public health problem and remains a serious concern and a drawback to its rapid economic development. According CAADP (2013), to under nutrition has long history and remains one of the major and most pressing health

problems in Ethiopia. Chronic under nutrition as measured by stunting and underweight, anemia, iodine, zinc and vitamin A deficiency indicates major nutritional problems of Ethiopia. The childhood deaths associated with malnutrition reaches 57%.

2.3. Dietary Diversity

According to IFPRI (2002), dietary diversity is the number of different foods or food groups consumed over a given reference period. Dietary diversity is a qualitative measure of food consumption that reflects household access to a variety of foods and is also a proxy for nutrient adequacy of the diet of individuals (FAO, 2010). The rationale for emphasizing dietary diversity in developing countries stems mainly from a concern related to nutrient deficiency and the recognition of the importance of increasing food and food group variety to ensure nutrient adequacy. Lack of dietary diversity is a particularly severe problem among poor populations in the developing world, because their diets are predominantly based on starchy staples and often include little or no animal products and few fresh fruits and vegetables (IFPRI, 2002).

2.3.1. The Dietary Importance of Potatoes

Potatoes are prepared by consumers in variety of means. Potatoes are usually eaten cooked, and most often eaten boiled and unpeeled in many regions of the world. Baking, boiling, dehydrating, and frying are employed world-wide. According to Englyst *et al*. (1992) cooking or processing of potatoes greatly improves the digestibility of potato starch, which has very low digestibility in the raw state since potato starch granules have a β-crystalline structure that is resistant to amylase digestion. Unpeeled potatoes that undergo cooking have better nutrient retention than do peeled potatoes and size reduction brings about further losses. Mary *et al*. (2009) indicated that boiling cut or peeled potatoes leads to loss of water-soluble vitamins and minerals due to their leaching out into the cooking water but baking, roasting, and frying generally result in lower losses of vitamins than boiling. On the other side baking cause's slightly higher losses of vitamin C than boiling, due to the higher oven temperatures, but losses of other vitamins and minerals during baking are lower (FAO, 2008).

According to FAO (2008) Potatoes, nutrition and diet report freshly harvested potato contains about 80 percent water and 20 percent dry matter. About 60 to 80 percent of the dry matter is starch. On a dry weight basis, the protein content of potato is similar to that of cereals and is very high in comparison with other roots and tubers. In addition, the potato is low in fat content. Potatoes are rich in several micronutrients, especially vitamin C – eaten with its skin, a single medium sized potato of 150 gram provides nearly half the daily adult requirement (100 mg). The potato is a moderate source of iron, and its high vitamin C content promotes iron absorption. It is a good source of vitamins B1, B3 and B6 and minerals such as potassium, phosphorus and magnesium, and contains folate, pantothenic acid and riboflavin. Potatoes also contain dietary antioxidants, which may play a part in preventing diseases related to ageing, and dietary fiber, which benefits health. In order to keep glycol-alkaloid content low and to insure healthy eating, potatoes should be stored in a dark and cool place. Under exposure to light potatoes turn green in color due to increased levels of chlorophyll. Since glycol-alkaloids are not destroyed by cooking, cutting away green areas and peeling potatoes before cooking ensures healthy eating (FAO, 2008).

2.4. Theoretical Models

2.4.1. Intensity of Improved Potato Varieties Adoption

Limited dependent variable model provides a good framework to study adoption behavior of farmers. The most commonly used qualitative models to study the adoption behavior are the logit and the probit models (Feder *et al*., 1985). These models specify a functional relationship between the probability of adoption and various explanatory variables (Bekele *et al*., 2000). However, this approach does not capture intensity of adoption. The tobit model overcome this problem by measuring both adoption and intensity (Mazvimavi &Twomlow, 2009). Intensity of adoption of potato varieties is the average size of land occupied by improved varieties, whereas the adoption rate of improved potato varieties is the percentage of farmers growing potatoes varieties (Tesfay *et al*., 2006).

Logit model: Logistic regression sometimes called the logistic model or logit model, analyzes the relationship between multiple independent variables and a categorical dependent

variable, and estimates the probability of occurrence of an event by fitting data to a logistic curve. There are two models of logistic regression, binary logistic regression and multinomial logistic regression. Binary logistic regression is typically used when the dependent variable is dichotomous and the independent variables are either continuous or categorical.

Tobit model: Tobit is appropriate model to deal with such censored data and used to analyze the intensity of use of improved varieties in preference to multiple regression model, when significant number of observations on dependent variable having a value zero (Endris, 2003). Area planted with improved variety of potato represents a censored distribution since half of the sample farmers assume a value of zero for not adopting (non-users). Accordingly, there is a cluster of households with zero adoption of the improved technology at the limit. The application of Tobit analysis is preferred in such cases since it employs both data at the limit as well as those above the limit (Gairhe *et al*., 2017).

2.5.2. Impact Evaluation

According to Amare *et al*. (2012) estimation of the impact of technology adoption on household welfare outcome variables based on non-experimental observations is not trivial because of the need of finding on counterfactual of intervention. The observed one is the outcome variable for adopters, in the case that they did not adopt. That is, we do not observe the outcome variables of households that adopt, had they not adopted (or the converse).

Improved varieties are not randomly distributed to the two groups of households (as adopters and non-adopters), but rather to the household itself deciding to adopt given the information it has, therefore the two group may be systematically different. Estimation of impact of improved potato varieties adoption on farm household nutrition based on non-experimental observations is significant because of the need of finding counterfactual of intervention. To address this missing counterfactual Khonje *et al*. (2015) use propensity score matching (PSM), endogenous switching regression (ESR), and inverse probability weighting (IPW) models used for impact analysis.

Propensity score matching: is an alternative method to estimate the effect of receiving treatment when random assignment of treatments to subjects is not feasible (Rizov *et al*., 2008). Propensity score matching is the most widely used type of matching, in which the comparison group is matched to the treatment group on the basis of a set of observed characteristics or by using the "propensity score" (predicted probability of participation given observed characteristics); the closer the propensity score, the better the match. The method tries to pick an ideal comparison that matches the treatment group from a larger survey. A good comparison group comes from the same economic environment (Baker, 2000). PSM tries to create the observational analogue of an experiment in which everyone has the same probability of participation. The difference is that in PSM it is the conditional probability (P(Z)) that is intended to be uniform between participants and matched comparators, while randomization assures that the participant and comparison groups are identical in terms of the distribution of all characteristics whether observed or not.

PSM does not require a parametric model linking outcomes to program participation. Thus, PSM allows estimation of mean impacts without arbitrary assumptions about functional forms and error distributions (Ravallion, 2005).

Endogenous switching regression model: Endogenous switching regression model use when both observable and unobservable characteristics are accounted for, thus controlling for a 'hidden bias' which can arise when unobservable variables are not taken into account. Ignoring the endogeneity of adoption of improved potato varieties would result in biased estimated parameters (Wabwile *et al*., 2016). According to Khonje *et al*. (2015) the average treatment effect on the treated (ATT) computes the average difference in outcomes of adopters category with and without a technology. Most commonly used methods to calculate ATT such as PSM ignore unobservable factors that affect the adoption process, and also assumes the return (coefficient) to characteristics to be same for adopters and non-adopters.

The differences in welfare outcome variables between those farm households that did and those that did not adopt improved technology could be due to unobserved heterogeneity. Not distinguishing between the casual effect of technology adoption and the effect of unobserved heterogeneity could.

Endogeneity of the adoption decision could account (that is, for the heterogeneity in the decision to adopt or not to adopt new technology and for unobservable characteristics of farmers and their farm) by estimating a simultaneous equations model with endogenous switching by full information maximum likelihood estimation (Solomon *et al*., 2010). The ESR framework proceeds in two stages: the first stage is the decision to adopt improved varieties, and this is estimated using a probit model; in the second stage an Ordinary Least Squares (OLS) regression with selectivity correction is used to examine the relationship between the outcome variable and a set of explanatory variables conditional on the adoption decision (Khonje *et al*., 2015).

2.6. Empirical Findings of Adoption

The adoption process is conceptualized to include several mental stages through which an individual pass after first hearing about an innovation and finally deciding to accept or reject it. This process generally includes five stages: awareness, interest, evaluation, trial, and adoption (Endris, 2003). Feder et al. (1985) noted that farmers are classified according to their tendency to adopt an innovation as innovators, early adopters, followers, and laggards. As noted by Feder et al. (1985), a complete analytical framework for investigating adoption process at the farm level should include farmer's decision making model determining the extent and intensity of use of a new technology at each point throughout the adoption process and a set of equations of motion describing the time pattern of parameters which affect the decision made by the farmer.

Ban and Hawkins (1996) indicated that people who are quick to adopt an innovation may be characterized by having many contacts with extension agents, active participation in many organizations, being well educated, and having a relatively high level of income and standard of living.

The intensity of adoption of new technologies that are divisible (such as high yielding varieties or new variable inputs) can be measured at the individual farm level in a given time period by the amount or share of farm area utilizing the technology (Feder *et al*., 1985). According to Patel *et a*l. (2012), farmers do not adopt a package of practices fully. There is only a partial adoption by them. As a result, the gap always appears between the

recommended production technology and their use at the farmer's field. Endris (2003) on his Adoption of Improved Sweet Potato Varieties revealed that; experience, the value of livestock, farmer's perception of yield, earliness in maturity and establishment performance of the improved varieties and extension contact positively influenced the probability of adoption and intensity of use of improved sweet potato varieties.

On the other hand, marginal changes in farm size and distance from the research center to the farm negatively influenced the adoption and use intensity of improved sweet potato varieties. For instance, if farming experience increased by one percent adoption and intensity of use of improved sweet potato varieties would increase by about 0.009% of which 0.005% is attributed to the increase in the intensity of use of improved varieties by those farmers already adopted new varieties. One percent increase in farm size decreases the probability of adoption and intensity of use of improved sweet potato varieties by 0.21% and 640.30%, respectively.

The estimated increase in the probability of adoption and intensity of use of improved sweet potato varieties resulting from a one percent change in the value of livestock owned is 0.00004% and 0.00005%, respectively, which were very small as compared to the changes resulting from other significant variables.

A change in the perception of the farmer on the yield of improved variety to be higher than that of local variety (i.e. a change from 0 to 1) brings about 0.20% increase in the probability of adoption and 0.29% increase in the intensity of use of improved sweet potato varieties. Farmer's perception of the earliness of the improved varieties increases the probability of adoption and intensity of use by about 0.095% and 0.14%, respectively.

Establishment performance of improved variety being better than that of local variety brings about 0.07% increase in the probability of adoption and 0.10% increase in the intensity of use of improved sweet potato varieties.

A marginal change in extension contact increases of the probability of adoption and intensity of use of improved sweet potato varieties by about 0.14% and 0.20%, respectively.

A one percent increase in the distance from research center to the farm reduces the probability of adoption and intensity of use of improved varieties by about 0.005% and 0.002%, respectively.

Mwanga *et al.* (1998) in Tanzania has indicated that household size, farm size and education level significantly affected the adoption of improved wheat varieties. They indicated that the adoption of fertilizer was significantly affected by the number of livestock owned, farm size, extension contact, hired labor and credit availability. Other studies on the adoption of improved technologies at farm level have been conducted in Ethiopia by Legese (1992) indicated that profitability is a function of elements of agro-climatic and socioeconomic environments and these factors indirectly affect the adoption patterns. He has pointed out that the probability of adoption of improved varieties and intensity of adoption of fertilizer and herbicide was influenced by experience, credit, cash down payment, participation in farmer organization as a leader and close exposure to technology.

Yohannes *et al.* (1990) reported that debt had a negative effect on the adoption of fertilizer and pesticides. Itana (1985) explained that distance to the extension center, education, farm size and adequacy of rainfall as major factors that affect the adoption of fertilizer and improved variety.

Alene *et al.* (2000) confirmed the importance of farmers' access to resources, extension services, and the availability of improved seed. Creating more opportunities for off-farm employment and income will enhance the financial ability of smallholder farmers to acquire external inputs. The fact that extension services are making a difference, it follows that policy makers need to focus on targeting resource-poor farmers who represent the farming communities in many areas of the country. At the same time, the availability of improved seed proved to be a major constraint for adoption, a fact that calls for improvements in improved seed delivery to effectively cope with the demands of small farmers.

The results of research by Legesse *et al.* (2001) showed that it is structural factors, in particular, oxen ownership and distance to market, that determining the adoption and intensity

of use of technologies compared to personal characteristics, extension activity, attitudes to prices or risk.

Farm size and farmers' perception of input prices were found to be significant with positive and negative effects, respectively, but these effects were not particularly robust across technology or crop mixes nor across model they specified. Farm income is another significant factor differentiating users from non-users and hence has implications for changing the existing input credit scheme (Alene, *et al.,* 2000).

These adoption studies undertaken in Ethiopia have extensively examined the factors that influenced adoption of improved technologies in few localities and most of them are centered on the adoption of new varieties of cereal crops, pesticides and fertilizer. No attempt has been made to study the adoption of root crops that feed many populations in Ethiopia (Endris, 2003).

According to Ketema *et al.* (2016), access to irrigation, extension contact frequency, farm size, membership to cooperatives, and annual income were found significantly determining the adoption of the potato technology package.

Farm size was hypothesized to positively influence the adoption of the potato technology package. However, the current result is against this expectation. The result shows that farm size was negatively affecting adoption of potato technology package. This could happen as the production of potato, unlike other crops, requires more intensive production managements that fit into smaller farms. This intensive management could in turn result in relatively higher productivity that further intensifies adoption of the package.

Membership to cooperative institutions was found positively driving the adoption of the potato technology package. This could happen given the fact that cooperatives are among the strongest social institutions that play an important role in the adoption of technologies.

Irrigation is an important factor that explains the production of potato. Farmers in the study area utilize irrigation for potato production and hence it enabled them to fetch a higher price

on the market. In line with this, farmers who used irrigation were found to be better adopters of potato technology package as compared to those who are not using irrigation.

Alene *et al*. (2000) on his adoption of recommended potato production technology study indicated that education, experience in potato cultivation, Social participation, land holding, annual income, irrigation facilities, extension contact, mass media exposure, participation in extension activity, economic motivation, scientific orientation, risk orientation, and knowledge levels are important factors in determining the adoption level of potato production technologies.

2.7. Conceptual Framework

This sub section clearly shows, the different factors that affect the adoption probabilities and use intensity of improved potato varieties, and the nutrition welfare outcomes.

The adoption and use intensity of improved potato varieties determined by demographic characteristics (sex, age, family and size), socio-economic factors (education, cultivated land size, livestock holding, farmer experience, perception on IPV yield and maturity period) and institutional factors (access to extension service, plot distance, woreda market distance access to irrigation and availability of prior neighbor adopter).

Similarly, the household's nutrition security is the outcome of several interactions of farmer internal and external factors. These factors are, demographic characteristics (sex, age, family size and dependency ratio), socio-economic factors (education, cultivated land size, livestock holding, farmer experience, number of fertile plots, number of plots with recommended rate fertilizer and off-farm income), institutional factors (woreda market distance) and adoption of improved potato varieties. Diagrammatic relationship of factor of IPV adoption, and nutrition outcomes are presented as follow.

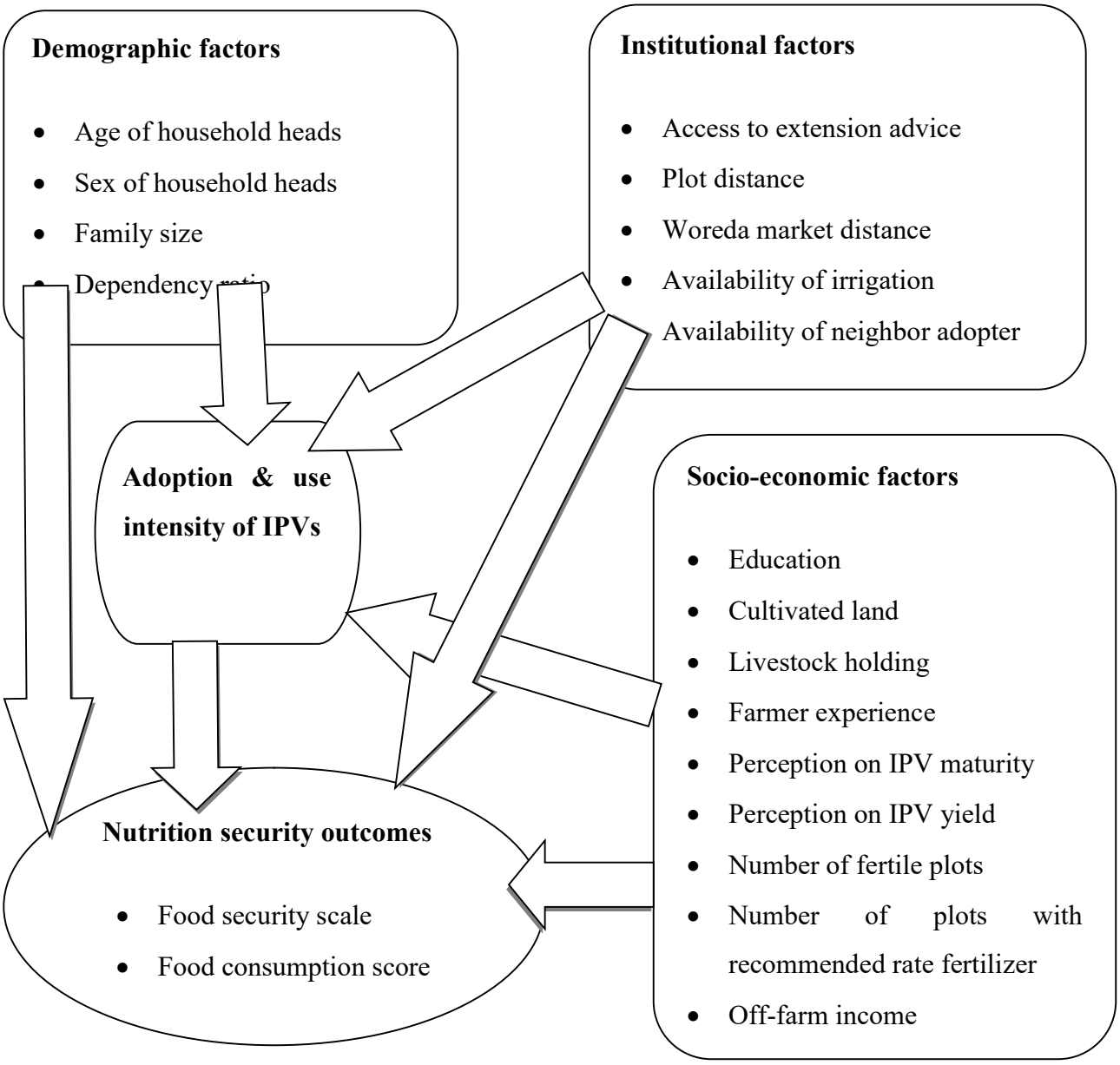

Figure 1: conceptual framework of the study

Source: Own design from literature reviewed, 2019.

3. METHODOLOGY OF THE STUDY

3.1. Description of the Study Area

This study was conducted at Emba Alaje *woreda*, one of the five districts of the southern zone of Tigray regional state. The *woreda* is selected relatively based on its widespread adoption of improved potato varieties. Emba Alaje is located about 90 km far from Mekelle, the capital city of Tigray Regional National State. Geographically, Emba Alaje *Woreda* is located 12º50'-13º 0' N latitude and 39º15'-39º 40'30"E longitude (figure2). The *woreda* is bordered with Hintalo wajirat in the north, Endamehoni in the south, Raya Azebo in the south east, and Amhara region in the south-west. The *Woreda* covers a total land area of 1677 square kilometer (WARDO, 2009).

Emba Alaje is among one of the highlands districts in Tigray having an average altitude of 2400 m.a.s.l. The *Woreda* is one of the densely populated areas and thus, small land-holding similar to most highlands of Ethiopia. According to the WARDO (2009) the area lies within three agroecological zones including highland (72%), mid-latitude (21%), and lowland (7%). The *Woreda* has bimodal rain fall pattern, summer is the main rainy season June to August (with its peak in July) and short rain season in from February to April. Moreover, rain falls has almost the same coverage in the districts sub districts with an average of 380 mm annually .The maximum temperature ranges from 24-degree cent grade to 36-degree cent grade while the minimum temperature ranges up to-6-degree cent grade on the peaks of EmbaAlage mountain (the second biggest mountain in Tigray with an altitude of 3956 m.a.sl. (Haylu, 2014).

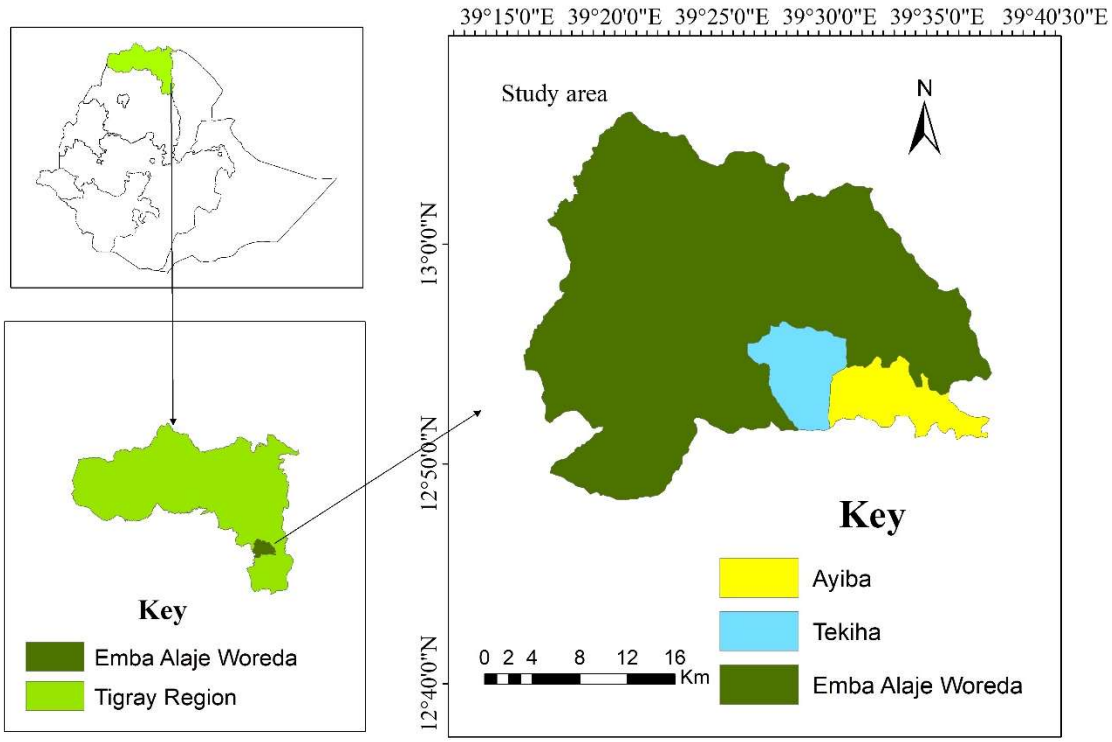

Figure 2: Location of the study area.

Source: (Authors compilation, 2019)

From the CSA (2007) population data, the current populations number of Emba-Alage W*oreda* is projected around 145746, from these 71331 are males and 74414 of them are females. In addition to this, the report showed that, there are about 33427 households, with an average family size of 4.36. Furthermore, 98.18 % of the woreda population is Tigray ethnic group; 1.4 % constitutes by AgawKamyr ethnic group and other ethnic groups made up of 0.42 of the population. In addition to this, only 10.46 % of the populations are considered literate. Meanwhile, 99.68% of the population follows Ethiopian Orthodox Christianity as their religion.

Agriculture is the most dominant means of livelihood of the population of the district. There are also a considerable number of people engaged in selling livestock, petty trading, livestock products and fuelwood selling. The main crops grown include are Wheat, Teff, faba bean, barley and potato where wheat is the dominant crop. The Meher cropping season begins late

June and continues up to end of December. Crops like wheat, Teff, Faba bean, Potato and arley planted in from June up to July and harvest up to end of December (Haylu, 2014).

3.2. Sampling Techniques and Research Design

The survey was conducted on Emba Aleje *Woreda*, where potato varieties are relatively widely produced. Two Sample kebeles namely, Tekiha and Ayba were selected based on potato production potential and accessibilities of sub-*kebeles*. The number of improved potato varieties producer households are very few as compared to the non-producers (households who did not produce any types of potato varieties). The total number of households in Tekiha kebel are 1837, out of this only 182 households were only producing potato, whereas in Ayba Kebele the total number of households are 1835, but only 200 households were improved potato producer in 2018. Therefore, instead of following proportional sampling for each group, the researcher has found it more useful to take a sample size of 50% from Improve potato producer and 50% from non-producer, which was done to increase the share of improve potato producer in the sample for the analysis. Since the majority of potato producers use improved varieties, the control groups were selected from non-producer households. Farmers in each kebeles were further stratified in to two groups, potato producer and non-producer. For each stratum, the sampling frame was prepared, and sampling units selected randomly. During the analysis, the sampling proportion was corrected by applying corresponding sampling weights for all observations. The assigned weights are calculated for each observation based on the calculation of quotient of percentage in the population and percentage in the sample. Accordingly, the improved potato user received a weight of $0.198(\frac{\frac{182}{1837}x\,100}{\frac{50}{100}x100})$ and $0.218\ (\frac{\frac{200}{1835}x\,100}{\frac{50}{100}x100})$ in Tekiha and Ayba kebeles, respectively. Using similar procedure, the non-producers receive weights of $1.8\ (\frac{\frac{1655}{1837}x\,100}{\frac{50}{100}x100})$ and $1.78\ (\frac{\frac{1635}{1835}x\,100}{\frac{50}{100}x10})$.

Since STATA has an advantage of incorporating the weight option, the corresponding sampling weights have been included during the analysis of impact estimation.

Table 1: Distribution of Sample households by Kebele

Sample kebele	Participant households		Non-Participants households		
	Total	Sample	Total	Sample	Total Sample
Tekiha	182	88	1655	94	182
Ayba	200	97	1635	91	188
Total	382	185	3290	185	370

3.2 Types and Sources of Data

Primary data was the main source of data for this study. The required data was collected through farm household survey using structured questionnaire. The survey was conducted on May 2018 when most farmers had enough time for interview. Experienced enumerators were recruited and trained in the class on each parts and questions for common understanding of questions and ethical issues during before and interview. Structured questionnaire was prepared and pre-tested, and the necessary modifications were made before it was used for the actual survey. Trained enumerators under the supervision of the researcher interviewed the sample farmers. The supervisor was responsible for the spot data editing and crosschecking to control the data quality. The interview also was supplemented by key informant interview and focus group discussion to obtain in-depth information. In addition to the primary data, secondary data were collected from review of different document which include research works and reports from the woreda office of agriculture, GRAD and Africa RISING projects.

3.3. Methods of Data Analysis

Descriptive and econometrics analysis were employed to analyze the collected data by using SPSS and STATA software. The most econometrics models commonly used in adoption and intensity of adoption are qualitative choice models including the linear probability function, logistic distribution function (logit), and normal distribution function (probit) and the Tobit model (Degu, 2000). In this study, Tobit model was applied to identify factors affecting the adoption and intensities of use of improved Potato varieties since advantage over other

adoption models in dealing with a dependent variable with censored distribution and generating information for both probabilities of adoption and intensity of use of the technology (Endris, 2003). Half of our sample households had zero value both in adoption probabilities and percentage of areas covered with improved potato varieties. To analyze the impact of improved potato varieties on households' nutrition propensity score matching and switching regression model. Household dietary diversity score (HDDS) and food consumption score (FCS), food security scale (FSS) outcome variables were used to measure the impact on nutrition as nutrition cannot be measured directly.

3.3.1. Descriptive Statistics

Descriptive statistics such as mean, percentage and standard deviation were used to characterize the farming system of the areas and analyze farmers' responses and their implications for adoption of improved potato varieties, proportion of households who consume a particular food group or nutrient-rich food, and the food consumption group (FCG). The frequency of DDS, FCS and FSS categories were also used to make comparisons between improved potato producer and no-producers. The t-test was employed for the comparison of different continuous variables or characteristics of farm households. Whereas, chi-square was used to compare categorical or dummy variables among IPV adopter and non-adopter households.

3.3.1.1. Household Dietary Diversity Score (HDDS)

According to FAO (2010) the HDDS provide an indication of household economic access to food and it was calculated by summing the number of food groups consumed in the household respondent over the 24-hour recall period. Respondents were asked whether they consumed the 12 food groups and their "yes" responses were coded as 1 and the negative response "no" coded as 0. The next step is summing the dietary diversity variable values of all new food groups and, the potential score ranges from 0 to 12 for HDDS. The higher score indicated that households consumed more diversified food groups. The HDDS of ≤ 3, 4-5 and ≥ 6 implies low, medium and high dietary diversity respectively (FAO, 2010).

3.3.1.2. Food Consumption Score (FCS)

According to VAM (2008) the FCS is a composite score based on dietary diversity, food frequency, and relative nutritional importance of different food groups and it can be calculated using the frequency of consumption of different food groups consumed by a household during the 7 days before the survey. The following four procedure are important to calculate the FCS, these are: (i) group all the food items (the 16 food items) into specific food groups (9 food groups), (ii) sum all the consumption frequencies of food items of the same group, and recode the value of each group above 7 as 7, (iii) multiply the value obtained for each food group by its weight (the standard weights for main staples 2, pulses 3, vegetables 1, fruit 1, meat and fish 4, milk 4, sugar 0.5, oil 0.5, condiments 0) and create new weighted food group scores and, (iv) sum the weighed food group scores, thus creating the food consumption score (FCS). FCS 0-21, 21.5-35, and >35 indicated poor, borderline, and acceptable household consumption respectively.

3.3.1.3. Food Security Scale (FSS)

According to Bickel, *et al*. (2000) the full range of food insecurity and hunger cannot be captured by any single indicator. Instead, a household's level of food insecurity or hunger must be determined by obtaining information on a variety of specific conditions, experiences, and behaviors that serve as indicators of the varying degrees of severity of the condition. Food insecurity cannot be measured directly. Therefore, to measure the food insecurity and hunger the 18 food security questions found to provide the statistically strongest set of indicator items for constructing a 12-month measurement scale. The sum of affirmative ("Almost every month", "Often true", "Sometimes true", and "Yes" coded as 1) and negative responses ("Never true", "only one or two months", "No", and questions that a household does not answer because it has been screened out, coded as 0) provide the FSS. According to Price *et al*. (1997) this measure expresses the household's level of food security or insecurity in terms of a numeric value that ranges between 0 and 10. The scale values of 0, indicating that household did not experience in the past year any of the conditions of food insecurity and the scale value 10 indicates the most severe level of food insecurity. Households with children having a scale value of 0-1.6 (0-2 affirmative response), 2.3-4.3 (3-7 affirmative

responses) and 4.7-6.4 (8-12 affirmative response) 6.8-10 (13-18 affirmative responses) out of the 18 food insecurity questions, classified into four food security status categories; these are, food secure, food insecure without hunger, food insecure with hunger, food insecure with severe hunger respectively. Household without children having a scale value of 0-2 (0-2 affirmative responses), 2.8 - 4.3 (3-5 affirmative responses), 5-6.5 (6-8 affirmative responses) and 7.5-8.2 (9-10 number of affirmative responses) also were classified in to food secure, food insecure without hunger, food insecure with hunger, food insecure with severe hunger respectively.

3.3.2. Specification of Econometrics Model

3.3.2.1. Tobit Model

According to McDonald and Moffit (1980), to identify factors of the probability and level of adoption of improved potato varieties the Tobit model was used, and it can be expressed mathematically as,

$$Y^* = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_n x_n \dots\dots + \mu_i = f(x_i)$$

Y = Y^*, $if\ Y^* > 0$ and Y= 0 $if\ Y^* \leq 0$ … … … … ……………………………… … … . eq (1)

Where Y = the observed dependent variable, in this case the proportion of area under improved potato varieties in the total cultivated areas since farmers in the study areas totally replaced the local varieties.

Y* = is the latent dependent variable, which is not observable, X = explanatory variable, β= a vector of Tobit maximum likelihood estimates, μi = an independently and normally distributed error term with mean zero and constant variance.

According to Tobin (1958), the expected value of use intensity of improved potato varieties across all observations was estimated by:

$$E(Y_I) = X\beta F\left(\frac{Y_m}{\sigma}\right) + \sigma f\left(\frac{Y_m}{\sigma}\right) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots . eq(2)$$

Where $F\left(\frac{Y_m}{\sigma}\right)$ and $\frac{x\beta}{\sigma}, f(\frac{Y_m}{\sigma})$ are the cumulative normal distribution function and the value of the derivative of the normal curve respectively.

$\frac{x\beta}{\sigma}, (\frac{Y_m}{\sigma})$ represents the normalized index at the mean values of all explanatory variables and the Z-scores for the area under the normal curve.

β and σ represents are the Tobit maximum likelihood estimates and the standard error of the error term respectively.

The marginal effect of an explanatory variable on the expected value of the dependent variable (proportion of area under improved potato varieties) is:

$$\frac{\partial E(Y)}{\partial x_i} = f\left(\frac{Y_m}{\sigma}\right)\beta_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(3)$$

The change in the probability of using a technology as independent variable Xi changes is:

$$\frac{\partial F(\frac{Y_m}{\sigma})}{\partial x_1} = f\left(\frac{Y_m}{\sigma}\right)\frac{\beta_1}{\sigma} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..eq(4)$$

3.3.2.2. Propensity Score Matching Model (PSM)

To address the second research objective, the Propensity score matching method was applied. In an experimental design, randomization ensures uniform/equal distribution of all relevant characteristics between treatment and control group and, because of this, the difference in mean outcomes correctly estimates the impact of the intervention. In the absence of randomization, however, the groups may differ not only in their treatment status, but also in their values of socioeconomic characteristics. In this case, it is necessary to account for these differences to avoid potential biases. Therefore, to avoid this potential bias PSM were applied and this method allows to create the comparable nonparticipants or counterfactuals to participants (Heinrich *et al*., 2010). The counterfactual was be identified by matching participant (improved potato grower) with nonparticipants (non-grower) which have similar pre-intervention characteristics, it is equally valid to match on the propensity score. The Method measures the impact of the intervention as the difference between the potential outcome in case of treatment and the potential outcome in the absence of treatment-

(Heinrich *et al*., 2010). For this study, the outcomes variables are HDDS, FCS and FSS. According to Heinrich *et al*. (2010) to apply the PSM for estimating the impacts of the intervention, in this case adoption of improved potato varieties, the following four procedures was used, these are:

(i) Generating propensity scores p(x)

The propensity score is estimated using various socio-demographic characteristics of farmers. These scores are probabilities that represent the households for adopting improved potato varieties given characteristics (X). The probability of participation summarizes all the relevant information contained in the X variables and as it allows for matching on a single variable (the propensity score) instead of on the entire set of covariates (Heinrich *et al*., 2010).

According to Gujarati (2003), the propensity score matching was generated using logit model and the model mathematically specified as follows:

$$pi = E(y = 1|X_i = \frac{1}{1 + e - (\beta_0 + \beta_1 x_i)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$Z_i = \beta_0 + \beta_1 x_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$p_i = \frac{1}{1 + e - z_i} = p_i = \frac{e^{z_i}}{1 + e^{z_i}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$Z_i = \beta_0 + \sum_{i=1}^{n} \beta_1 x_i + \mu_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where, p is the probability of participation in improved potato varieties production

i =1, 2, 3 -- n (number of observations)

β0 = the intercept

βi = the slope of regression coefficients to be estimated xi = intervention characteristic of households

μi = disturbance term or error term or stochastic variable

The probability that a household belongs to non-improved potato producer is:

1-Pi= $\frac{1}{1+e^{zi}}$----------(5)

As indicated above, using the explanatory variable the logit model for this study was specified as follows.

Yi=α+β1Sex +β2Age +β3EduHH +β4HHsize +β5Sizeofland +β6TLU +β7Farmexpr +β8Extensiona +β9Closerpd+ β10Irracces + β11Neighbor + β12ipvmaturityP + β13ipvyield+ů----------(6)

(ii) Choose a Matching Algorithm

The idea of matching is identifying control and treated individuals with the same or similar propensity score. Once an estimated propensity score is obtained, different matching algorism was used to match comparison units with treated units. The most commonly employed matching algorisms are the nearest neighbor, kernel matching, stratification matching, caliper matching and radius matching (Heinrich *et al*., 2010). For this study, the PS of treated households (user) was matched with counterfactual households (non-user) using the nearest neighbor, kernel, caliper and Radius matching estimator methods. To do the matching, three important tasks should be done first. The first task is, generating propensity score (probability of participation) based on the selected covariates. The second task is imposing the common support condition on the propensity score distribution of the sample households. The common support region is region between the higher value of the minimum and the lower value of maximum propensity score of the treated or control groups. The last task before matching is discarding observations whose propensity score is outside common support region.

Nearest neighbor matching - one of the most straightforward matching procedures. An individual from the comparison group is chosen as a match for a treated individual in terms of the closest propensity score (or the case most similar in terms of observed characteristics). The nearest neighbor matching with replacement methods was used to match untreated individual more than once as a match. Using nearest neighbor ensure the use of the most similar observation to construct the counterfactual.

Kernel matching - compare the outcome of each treated person to a weighted average of the outcomes of all the untreated persons, with the highest weight being placed on those with scores closest to the treated individual. One major advantage of this approach is the lower variance, which is achieved because more information is used.

Radius matching -specifies a "caliper" or maximum propensity score distance by which a match can be made. It uses all of the comparison group members within the caliper.

According to Heinrich *et al*. (2010) to estimate the impact of a program correctly; PSM requires two main conditions, the conditional independence assumption and the common support condition.

Conditional independence assumption: The assumption assesses the quality of matching to perform tests that check whether the propensity score adequately balances characteristics between the treatment and comparison group units. It verifies the treatment is independent of unit characteristics after conditioning on observed characteristics: $D \perp X \mid p(X)$. After the application of matching, there would not be statistically significant differences between covariate means of the treatment and comparison units. The inclusion of the variables is based on the conditional independence assumptions. Relevant variables related to the intervention and outcome were considered in the propensity score function (Heckman *et al*.,1997). According to Caliendo and Kopeinig (2005), the inclusion of non-significant variables would not bias the estimates or make them inconsistent. On the other hand, including the full set of covariates in small samples might cause problems in terms of higher variance, since either some treated have to be discarded from the analysis or control units have to be used more than once.

The Common Support Condition Assumption: It helps to investigate the validity or performance of the propensity score matching estimation to verify the common support or overlap condition. The assumption is critical to estimation, as it ensures that units with the same X values have a positive probability of being both participants and nonparticipants: $0 < P(D = 1 \mid X) < 1$.

Checking of the overlap or region of common support between treatment and comparison groups was done by using visual inspection of histograms or density-distribution plots of propensity scores before and after matching for both groups.

Testing the matching quality: The basic idea of all approaches is to compare the situation before and after matching and check if there remain any differences after conditioning on the propensity score (Caliendo and Kopeinig, 2005). In impact estimation using propensity score matching, we do not condition on all explanatory variables rather on the propensity score. Hence before proceeding to impact estimation we have to check if the matching procedure is able to balance the distribution of the relevant variables in both the control and treatment group. The main purposes of PSM are comparing welfare outcome variables between adequately balanced PS of treated and control groups. Therefore, the matching algorism quality is measured with the balancing power of all covariates and PS. After identifying the common support region using different matching algorism, matching was done between adopter and non-adopter households. For this matching, nearest neighbor, kernel, radius and caliper matching algorism were used. Balancing test, pseudo R^2 and the size of matched sample are the criterion to decide the final choice of matching estimator. According to Deheja and Wahba (2002), matching estimator which balanced all covariates of the two groups, bears low pseudo-R^2 and large matched sample size is the most preferable.

(iii) Estimate the average treatment effect (ATT)

The main aim here is to compare the level of change of HDDS, FCS and FSS as a measure of food and nutrition security per household heads between improved potato user and non-user farmers. Let Yi =1 and Yi =0 be the HDDS, FCS and FSS for treatment group (improved potato varieties producer) and control group (non-producer households) respectively.

The impact of a treatment for an individual is the difference between the potential outcome in case of treatment and the potential outcome in absence of treatment.

$$\Delta I = Y_{1i} - Y_{0i} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots eq(1)$$

Where,

ΔI is impact of treatment for i^{th} household,

Y_{1i} is outcome of the i^{th} treated household and

Y_{0i} is outcome of the i^{ht} untreated household

The mean impact of the intervention obtained by averaging the impact across all the individuals in the sample population. This parameter is known as average treatment effect or ATE:

$$ATE = E(\Delta I) = E(Y_1 - Y_0) \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots eq(2)$$

Average Treatment Effect on the Treated, or ATT measures the impact of the program on participant household.

$$ATT = E(Y_1 - Y_0|D = 1) \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots . eq(3)$$

The Average Treatment Effect on the Untreated (ATU) measures the impact that the intervention for untreated household if they would have treated (participated).

$$ATU = E(Y_1 - Y_0| D = 0) \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots .. eq(4)$$

E (Y0) | D =1 is average outcome of treated individuals obtained in the absence of treatment, which is not observed. E (Y0 | D = 0) is the average outcome of untreated individual obtained without treatment.

(iv) Sensitivity Analysis

In the application of PSM sensitivity analysis is the last step. The estimation of treatment effects with matching estimators is based on observable characteristics (Caliendo and Kopeinig, 2005). According to Becker and Caliendo (2007) matching based on conditional independence assumption, states that all variables simultaneously influencing the participation decision and outcome variables should be considered. Treatment effect estimation based on the observable may result the hidden bias if unobservable variables which affect both the participation and the outcome variables simultaneously are not considered.

Estimating the magnitude of bias with quasi-experimental data is not possible and the matching estimators are not robust against hidden biases. Hence, to check whether the

average treatment effect is altered by the hidden bias or not Caliendo and Kopeinig (2005) suggested the sensitivity analysis. To check the sensitivity of the estimated Average Treatment Effect (ATT) the Rosenbaum bounds were calculated for treatment (IPVs in our cases) effects that are positive and significantly different from zero (Rosenbaum, 2002). The P-critical value or upper bound of Wilcoxon significance level -Sig+ significance was checked. The significant P-critical value indicates the inclusion of all-important covariates that affect both participation and outcome variable, and the estimated ATT would be the pure effect of the treatment.

3.3.2.3. Endogenous Switching Regression Models (ESRM)

In impact estimation, propensity score methods are not consistent estimators in the presence of hidden bias. The method does not depend on functional form and distributional assumptions. It compares the observed outcomes of technology adopters with the outcomes of counterfactual non-adopters (Heckman *et al*., 1998). Propensity score matching does not help much when there are unobservable factors affecting the improved potato varieties adoption decision and the outcome variables, FSS, FCS and HDD in our case.

The welfare outcome of the treatment is not observed for adopter groups if they had not adopted and for non-adopter groups if they had adopted. Improved technology is not randomly distributed to the two groups of the households (adopters and non-adopters), but rather the households themselves deciding to adopt or not to adopt based on the information they have. Under the existence of such selection problem, the effect of the treatment on the outcome variables might be biased (Jaleta, 2016). Analysis of data that is nonexperimentally collected, the selection into the treatment could not be independent of the error terms of the outcome equations (DiPrete and Gangl, 2004). Under this circumstances, the treatment variable is endogenous, and the estimate obtained from matching methods would be biased. PSM deals the structural difference based on the observed variable and it assumes the return (coefficient) to characteristics to be same for adopters and non-adopters. However, the difference between adopters and non-adopters might be more systematic due to the potential interaction between IPV adoption decision and outcome variable (Solomon and Shiferaw, 2010)

Application of ordinary least squares to examining the impact of adoption of technologies on welfare outcomes might yield biased estimates. Because OLS assumes that adoption of improved technology is exogenously determined while it is potentially endogenous. The adoption decision is voluntary and may be based on individual self-selection.

Thus, for this study to consider the structural difference and selection bias (Seng, 2016), and to complement the PSM techniques and assess consistency of the results with different assumptions, endogenous switching regression techniques was applied (Solomon and Shiferaw, 2010).

Therefore, to correct the section bias and control unobserved farm and household characteristics Endogenous switching regression is the most appropriate methods.

3.3.2.3.1. Switching Regression Model Specification

Let A_i*= be the latent variable that capture the benefit from adopting IPV by i^{th} farmers and specified as follow.

$$A_i^* = Z_i\alpha + \varepsilon_i \; where \;\; A_i^* = \begin{cases} 1 \; if \; Z_i\alpha + \varepsilon i > 0 \\ O \qquad otherwis \end{cases} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where A_i is a binary variable equal to 1 if a farer adopts IPV and 0 if not. Z is a vector of plot, household, and village level variable that affect the decision to adopt or not to adopt IPV, and ε is an error term normally and independently distributed with mean 0 and variance σ^2. The

The first stage equation capture factor governing participation in IPV production and used to construct the selectivity term known as “mills ratio”, which is added to the second stage equations. Here, the first step is getting the Probit estimation of IPVs adoption decision factors and generating the mills ratio for both adopter and non-adopter groups. Since the Probit model assumes that the error term follows a standard normal distribution, the inverse Mills ratio should be generated from the estimation of a Probit model.

The welfare outcome of the household expressed as

$$Y_i = X_i\beta + \gamma A_i^* + \mu_i \ldots\ldots (2)$$

Where X is a vector of the plot, household, farm and village level variables that affect the FSS, FSC and HDD. γ Capture the effects of IPV adoption on the welfare outcomes. However, both the decision to adopt IPV and plot allocation to IPV are not random, rather selected by the farm households and dummy variable A_i^* cannot be treated as exogenous. In such self-section problem, the estimates of A_i^* might be biased and leads to over or underestimate of the IPV adoption on the welfare outcomes. Inclusion the mills ratio in the second stage equations helps for controlling bias due to sample selection (Heckman, 1979). According to Zaman (2001) the inclusion of extra term the "mills ratio", the coefficient in the second stage 'selectivity corrected' equation is unbiased.

According to Solomon and Shiferaw (2010), to account the selection biases, we could adopt an endogenous switching regression model of welfare outcomes, (i.e. FSS, FCS and HDD) where households face two regimes (1) to adopt, and (2) not to adopt defined as follows:

Regime 1: $Y_{1i} = X_i\beta_1 + \mu_{1i}\ if\ A_i = 1 \qquad (3a)$

Regime 2: $Y_{2i} = X_i\beta_2 + \mu_{2i}\ if\ A_i = 0 \qquad (3a)$

Where Yi is FSS, FCS and HDD in regimes 1 and 2, Xi represent a vector variable that influence the welfare outcome variables.

If a correlation exists between the error term of the outcome equation (3a) and (3b) and the adoption equation (1), estimating (3a) and (3b) without accounting leads to a biased estimate (Jaleta *et al*., 2016). Thus, for IPV adopter and non-adopter, the outcomes equation (FSS, FCS and HDD) corrected for endogenous adoptions as is given as:

Regime 1: $Y_{1i} = \beta_1 X_i + \sigma_{1\varepsilon}\lambda_{1i} + \eta_{1i}, \qquad if\ A_i = 1 \qquad (4a)$

Regime 2: $Y_{1i} = \beta_2 X_i + \sigma_{2\varepsilon}\lambda_{2i} + \eta_{2i}, \qquad if\ A_i = 0 \qquad (4b)$

Where, $\lambda_{1i} = \frac{\phi(Z_i\,\alpha)}{\Phi(Z_i\,\alpha)}$ $and\ \lambda_{2i} = \frac{\phi(Z_i\,\alpha)}{1-\Phi(Z_i\,\alpha)}$ are the invers mill's ratio (IMRs) computed from the Probit model of the selection equation to correct the selection bias in the second stage estimation. β and σ are the parameter to estimated, and η is an independently and identical distributed error term with mean zero and constant variance.

Following the two regime of the outcome equations, 4(a) and 4(b) the actual and the counterfactual welfare outcomes (FSS, FCS and HDD) is defined as follows

$$(a)\quad E[y_1|\,X,\,A_i = 1] = X_{1i}\,\beta_1 + \sigma_{1\varepsilon}\lambda_{1i}\quad (IPV\ user) \qquad (5a)$$

$$(b)\quad E[y_2|X,\,A_i = 0] = X_{2i}\,\beta_2 + \sigma_{2\varepsilon}\lambda_{2i}\quad (IPV\ non\ user) \qquad (5b)$$

$$(c)\quad E[y_2|X,\,A_i = 1] = X_{1i}\,\beta_2 + \sigma_{2\varepsilon}\lambda_{1i}\quad (IPV\ user\ had\ they\ been\ non\ user\ ) \qquad (5c)$$

$$(d)\quad E[y_1|X,\,A_i = 0] = X_{2i}\,\beta_1 + \sigma_{1\varepsilon}\lambda_{2i}\quad (IPV\ non\ user\ had\ they\ been\ user) \qquad (5d)$$

Equation (5a) and (5b) represent the actual expectations observed in the sample, whereas equation (5c) and (5d) represent the counterfactual outcomes.

we could calculate the average effect of the treatment (IPV adoption) on the treated (ATT) as the difference between (a) and (c), is specified as:

$$ATT = (a) - (c) = E[y_1|\,X,\,A_i = 1] - E[y_2|X,\,A_i = 1] = X_{1i}(\beta_1 - \beta_2) + \lambda_1(\sigma_{1\varepsilon} - \sigma_{2\varepsilon})$$

Similarly, we calculate the effect of the treatment on untreated (ATU) as an average effect of the treatment on untreated (ATU) for the farm households that actually did not adopt IPV as the deference between (d) and (b). Mathematically specified as:

$$ATU = (d) - (b) = E[y_1|\,X,\,A_i = 0] - E[y_2|X,\,A_i = 0] = X_{2i}(\beta_1 - \beta_2) + \lambda_2(\sigma_{1\varepsilon} - \sigma_{2\varepsilon})$$

The deference between ATT and ATU shows the transitional heterogeneity effect of the treatment. The positive value indicated that the effect of the treatment on the welfare outcome is higher for IPV adopter than the counter factual.

3.4. Definition of Variables and Hypothesized Relationships

The theoretical model of this study considered several research questions related to adoption of improved potato varieties include farm, farmer, technology specific characteristics and the impacts of the technology (IPV). The adoption model assumed that the dependent variable to be defined participation in growing of improved potato varieties and, HDDS, FCS, and FSS outcome variables which depends on the following explanatory variables: age of household head, education of the household head in years of schooling, gender of the household head, involvement of the household in off farm activities, farming experience of the household head in years, dependency ratio, total farm size owned in hectare, number of fertile plot owned, number of plot with recommended fertilizer rate, value of livestock owned in TLU, farmers' perception of varietal characteristics such as yield, earliness or maturity period, extension service, distance of the plot from the homestead, availability of neighbor adopter and, access of irrigation.

3.4.1. Dependent Variables

The dependent variables for this study are participation in growing of improved potato varieties (selection dependent variable), Percentage of area under improved potato varieties and nutrition security indicator (FSS, FCS and HDDS variables).

Participation in growing of improved potato varieties: It is a binary dependent variable with a value of 1 for improved potato variety producer and 0 for non-producer households.

Intensity of improved potato variety adoption: It is a continuous variable measured interim of percentage, which refers to the proportion of area of land allocated for improved potato varieties to the total cultivated land areas.

$$Intensity\ of\ IPV\ adoption = \frac{Area\ under\ improved\ potato\ varieties}{The\ total\ cultivated\ land} x100$$

3.4.2. Outcome Variables

Household dietary diversity Score (HDDS): is meant to reflect, in a snapshot form, the economic ability of a household to access a variety of foods. It is meant to reflect, the economic ability of a household to consume a variety of foods (FAO, 2010). The variable values range from 0-12.

Food Consumption score (FCS): is a proxy indicator for food security which able to capture both Dietary Diversity and Food frequency. It is continuous variable in which its value ranges from 0-112.

Food security scale (FSS): is a variable which measure the household's level of food security or insecurity in terms of a numeric value that ranges between 0 and 10.

3.4.3. Independent Variables

The following explanatory variables are hypothesized to determine adoption and use intensity of improved potato varieties of the household in the study area.

Sex of the household head: It is dummy variable which takes 1 if the household head is male and 0 if female. Male headed households are expected to be the better adopter, since potato needs intensive management practices. Lavison (2013) indicated male farmers were more likely to adopt organic fertilizer unlike their female counterparts.

Age of the household head: It is continuous variable measured in years. The age of the farmers may build or erode confidence on agricultural technologies. Farmer age may negatively influence both the decision to adopt and extent of adoption of improved potato varieties. Older farmers are more risk averse than younger farmers and have a lesser likelihood of adopting new technologies (Shah, 2012). On the other hand, older farmers have more experience in farming and knowledge on agricultural technology, and hence a higher probability of adopting new technologies. Therefore, age of the household head may positively or negatively affect improved potato varieties adoption.

Education level of the household head: It is a discrete variable which refers the level of education completed by household head (whether the household head is illiterate, read and write, primary, junior, secondary or tertiary). It is an essential factor for implementation and adoption of improved technologies. Education increases the ability of farmers to use their resources efficiently and the allocative effect of education enhances farmer's ability to obtain, analyses and interpret information. Mahadi *et al*. (2012) reports education has a significantly influence the adoption on factors affecting the adoption of improved sorghum varieties.

Family size: This variable is continuous variable which refers to the number of family members in a household. Family size is an important factor for adoption of technologies since large rural households have more labor for farming activities and potato needs intensive management. In the other way, households with high family size are risk avert and my not have confidence to allocate their plot for new varieties. As a result, the family size may positively or negatively affect the participation in potato production. Temesgen *et al. (2019*) reported that, the larger the size of the household, the better the chance of adapting to climate change. On the other hand, Belkele and stein (1998) indicated the negative effect of family size on adoption of land conservation technologies.

Land holding size: it is Continuous variable. It refers the size of the lands that the household currently own and cultivate (measured in hectare). The larger plot size allows farmers to diversified crops, and to reduce fear of crop loss. Thus, land size was hypothesized to affect the IPV production participation positively. Small holder farmers are highly risk averse to apply innovation due to limited holding and uncertain outcome of technology (Mesay *et al*., 2013)

Livestock holdings: it is Continuous variable. It refers the number of livestock the household own currently, and livestock size is important factor to access cash and purchase inputs. However, households with a higher livestock size prefers to produce cereal crops for its residue to feed their animals. Crop residue is the major source of livestock feed in dry season (Tilahun *et al.,*2016), and households with large number of livestock produce needs high biomass crops. As result, increase in size of livestock holding reduces the participation in production of IPV.

Farming experience: it is a continuous variable measure in years. Households with better farming experience is expected to be better in adoption and use intensity of technologies. Ainembabazi and Mugisha (2014) reported a positive influence of farming experience on agricultural technology adoption.

Access to extension advice: It is dummy variable taking the value of 1 if any member of household access extension advice and 0 otherwise. Extension is the main source of the information farmers to aware about the new crop varieties and access to extension expected to increase the participation in IPV production. Akudugu *et al.* (2012) reported the positive and significant effect of education on adoption of modern agricultural technologies.

Distance of the closer plot from the homesteads: it is a continuous variable measured in walking minutes. Potato needs the most fertile plots for better tuber yield, and the closest plot has relatively better soil fertility because of organic matter application and frequent visits (e.g. backyard). Due to this reason positive relationship is expected between the closer plot and participation in IPV production. Plot distance from the home stead negatively related with probabilities of chemical fertilizer adoption decision and it was statistically significant at 5% significance level (Berihun *et al.,* 2014)

Access to irrigation: It is dummy variable taking the value of 1 if the household use irrigation and 0 otherwise. Irrigation helps to produce potato after harvesting the main season crops. For better tuber production potato needs enough water until it matures well. To get the desire yield, during rain shortage it should be supplemented with irrigation. According to Kaguongo *et al*. (2018) irrigation water is important in crop production especially where rain water is not adequate, is unreliable and where farmers want to synchronize harvesting with high prices in the market. As a result, it was hypothesized that having irrigation would have a positive relationship with IPV production.

Availability of neighbor adopter: It is dummy variable taking the value of 1 if the household had neighbor IPV adopter and 0 otherwise. Farmers learn, build trust and confidence when they see the performance of new crop varieties practically. In addition, the neighbor adopter could be the source of seed and could be a means other to adopt improved

potato varieties. Thus, availability of neighbor adopter hypothesized positively to affect adoption of improved potato varieties. Foster and Rosenzweig (2010) reported that technology adoption by an individual farmer is positively correlated with the extent of prior adoption by his or her neighbors.

Farmers' perception on tuber yield: it is dummy variable 1 if the farmer thought the improved variety was superior to local varieties in terms of tuber yield and 0 otherwise. The positive perception on tuber yield and participation in IPV production expected to have positive relationships.

Farmers' perception on maturity period: it is dummy variable 1 if the farmer thought the improved variety was superior to local varieties in terms of short maturity period and 0 otherwise. The positive perception on short maturity and participation in IPV production expected to have positive relationships. The characteristic of the technology plays an important role in farmers adoption decision process. Farmers who perceive the technology being consistent with their needs and compatible to their environment are likely to adopt since they find it as a positive investment (Mignouna *et al*., 2011).

Table 2. Summary of independent variables and their expected signs

Variables	Notation	Category	Measurement unit	Sign
Sex of the household head	Sex	Dummy	1=male,0=female	+ve
Age of the household head	Age	Continuous		-/+ve
Education level of the household head	EduHH	Discrete	Number	+ve
Family size	HHsize	Discrete	Number	-/+ve
Land holding size	Sizeofland	Continuous	Number	+ve
Livestock holdings	TLU	Continuous	Number	-/+ve
Farming experience	Farmexpr	Continuous	Years	+ve
Access to extension advice	Extensiona	Dummy	1=yes, 0=no	+ve
Distance of the closer plot from the homesteads	Closerpd	Continuous	Walking minutes	-ve
Availability of irrigation	Irracces	Dummy	1=yes, 0=no	+ve
Availability of neighbor adopter	Neighbor	Dummy	1=yes, 0=no	+ve
Households Perception on IPV maturity	ipvmaturityP	Dummy	1=yes, 0=no	+ve
Households Perception on IPV yield	ipvyiiel	Dummy	1=yes, 0=no	+ve

4. RESULT AND DISCUSSION

In this chapter we presented the main results and discussion of the study. The data analysis performed in two main steps. In the first section, description of the sample household socioeconomics characteristics comparing adopter and non-adopter of IPVs is presented and, the second section presents the econometrics estimation results on the impacts of improved potato varieties adoption on household welfare outcomes (FSS, FCS and HDD).

4.1. Descriptive Statistics of Sample Households' Characteristics

Demographic and socio-economic characteristics such as, sex, age and education of the household head, family size, farming experience, distance of the plot, irrigation and extension access, livestock holding and perception on technologies are the commonly used variable in adoption studies. From table 3, 4 and 5 summarizes the mean standard deviation, t-test and $\chi 2$ of important variables.

From the finding of this study, in the study areas out of the 3672 total households 382 of them were only produced improved potato varieties. There is no local potato variety producer. This is because of the drawback of the local variety and other social and environmental factors farmers were replaced it by improved varieties.

Family size: The average family size for adopter and non-adopters almost similar, 5.84 and 5.58 respectively. The statistical association between family size and adoption of IPV is negative but insignificant.

Land holding size: Table 3 indicated that land size per household is very small, the average holding land size is 0.73 hectare. Improved potato adopter had relatively larger plot (0.82 hectare) and IPV non-adopter had smaller land holding size (0.654 hectare). The minimum and maximum land holding size were found 0.125 and 2 hectares respectively. The relationship between land holding size and adoption of improved potato varieties is negative but significant at 1% significance level both for IPV adopters and non-adopters.

Plot distance: Improved potato adopter had relatively closer plot on average than the non-adopter categories, which is 1.2 and 18.5 minutes respectively for adopter and non-adopter. The t-test result sows that there is positive and significant at 1% significance level.

Livestock holding: Number of animals owned in tropical livestock unit was 3.4, 3.7 and 3.06 for IPV adopter and non-adopter respectively. There was negative and significant relationship between livestock holding size and adoption of IPV at 5% significance level.

Table 3: Descriptive statistics of sample households (continuous variable)

	User (n=185)	Non-User (n=185)	Total (n=370)	
	Mean	Mean	Mean	t-value
Age of the household head (in years)	43.03(11.96)	44.8 (13.13)	43.92 (12.57)	1.35
Size of the household (number)	5.84 (1.92)	5.58 (1.94)	5.71 (0.10)	-1.32
Farming experience (in years)	21.24 (11.49)	21.99(12.49)	21.62 (0.62)	0.60
Education of the household head (years)?	2.43 (1.52)	2.27 (1.48)	2.35 (1.50)	-1.00
The size of land owned (hectare)	0.82 (0.37)	0.65 (0.29)	0.73 (0.34)	-4.62***
The closest distance (walking minutes)	10.17 (8.97)	18.49 (12.53)	14.33 (0.60)	7.35***
Livestock holding in Tropical livestock unit	3.70 (2.83)	3.06 (2.62)	3.38 (0.14)	-2.27**

Notes: Standard deviations are given in parentheses.

*** and ** denotes statistic test significance at 1 and 5 percent level.

Extension service: Table 4 below presented about, 87% and 34.6% of adopter and non-adopter, while from the total sample, 60.6% of the households had got extension advice. There were positive and significant relationships between extension advice and adoption of IPV at 1% significance level.

Irrigation access: Access to irrigation is another important characteristic of the farming households, on average 58.1 of the sample households had irrigation access. The 66.5 and 49.7

% of participant and non-participant household had irrigation access respectively. The mean difference of irrigation access between the participant and no-participant groups is significant at 1% significance level. The relationship of irrigation access and adoption of IPV is also positive.

Neighbor adopter: About, 91% of the adopter farmers had neighbor adopter. The relationship between neighbor adopter and IPV adoption is positive and significant at 1% significance level. A positive association between

Perception on maturity period: Table 3 shows the mean difference between adopter and non-adopter was significantly differ in perception of IPV maturity period at 1% significance level. About, 80% and 55.5% of adopter and non-adopter farmers respectively perceived IPV mature in shorter period than the local varieties.

Perception on tuber yield: As indicated in table 3 there was a significant mean difference between adopter and no-adopter in perception of IPV tuber yield potential at 1% significance level. The 86.5 % and 38.4% of adopter and non-adopter perceived IPV provided better tuber yield than the local variety.

Table 4: Descriptive statistics of sample households (dummy variables)

	IPV user (n=185)		IPV non-user (n=185)		Total (n=370)		
	Freq.	Percent	Freq.	Percent	Freq.	Percent	$\chi 2$
Sex of the household head?							
Female	35	18.9	39	21.1	74	20.0	0.27
Male	150	81.1	146	78.9	296	80.0	
Access to extension advice							
No Ext Access	24	13.0	121	65.4	145	39.2	106.71***
Access	161	87.0	64	34.6	225	60.8	
Access to Irrigation							
No Irr Access	62	33.5	93	50.3	155	41.9	10.66***
Irr Access	123	66.5	92	49.7	215	58.1	
Neighbor adopter?							
No Neighbor Adopter	16	8.6	171	92.4	187	50.5	259.76***
Neighbor Adopter	169	91.4	14	7.6	183	49.5	
Farmer's IPV Maturity period perception?							
No better maturity	37	20.0	83	44.9	120	32.4	28.02***
Better Maturity	148	80.0	102	55.1	250	67.6	
Farmer's IPV tuber yield perception							
No better yield	25	13.5	114	61.6	139	37.6	-10.98***
Better yield	160	86.5	71	38.4	231	62.4	

*** denotes statistic test significance at 1 percent level.

Table 5 shows that, the mean differences between the adopter and non-adopter were highly significantly different in household dietary diversity, food consumption and food security categories. The 11.9%, 32.4%, and 55.7% of adopter households are under low, medium and high food diversity categories respectively. Majority of the non-adopter farmers (48%) are under medium food diversity categories, while many of the adopter farmers (56%) are under high diversity category. Around 76% and 55% of adopters and non-adopter had acceptable level of food consumption respectively. More than 60% of adopters were food secured and 39% of them were food insecure without huger, which is consistent with CAADP report (2016). The 66 % of non-adopters were food insecure without hunger and 32% them are food insecure with moderate hunger.

Table 5: welfare outcome and categories of sample farmers

	IPV user (n=185)		IPV non-user (n=185)		Total (n=370)		
	Freq.	Percent	Freq.	Percent	Freq.	Percent	χ2
Household dietary diversity score categories							
Low	22	11.9	53	28.6	75	20.3	43.12***
Medium	60	32.4	89	48.1	149	40.3	
High	103	55.7	43	23.2	146	39.5	
Food consumption score categories							
Borderline	45	24.3	99	53.5	144	38.9	33.15***
Acceptable	140	75.7	86	46.5	226	61.1	
Food security scale categories							
Food secured	112	60.5	3	1.6	115	31.1	173.27***
Food insecure without hunger	72	38.9	122	65.9	194	52.4	
Food insecure with moderate hunger	1	.5	59	31.9	60	16.2	
Food insecure with sever hunger	0	0	1	.5	1	.3	

4.2. Econometric Analysis

4.2.1. Factor Affecting Adoption of Improved Potato Varieties

There were attempts to include all theoretically important variables in the model, however we excluded those variables which had week influence on adoption of improved potato varieties. Since R-squared represents the improvement in the goodness-of-fit, the increase in R-square when each variable is added to a model was considered for variable inclusion. The result in table 6 shows that, extension advice, availability of neighbor adopter, closeness of the plot from the homestead and positive perception on the maturity periods are highly significant (significance at 1% significance level) and the relationship with adoption of IPV is positive except the closeness of the plot. Positive perception on tuber yield potential and the size of farm owned were also significant at 5% and 10% significance level.

The farm size was positively related with adoption of improved potato varieties and its coefficient was significant at 1% probability level. On average each additional hectare of land increases the probability of adoption of IPV by 16%. The reason for this could be, farmers primarily allocate their land for main staple foods crops and a larger land size may allow farmers to allocate their plot for different food and other cash crops, such as potato and vegetables. The shows that, the positive and significant relationship between land size and adoption of improved potato varieties. The result of this study was consistent with prior expectation and Beriso (2017) report on his Adoption of improved potato varieties.

Distance of the plot from the homestead was negatively related with adoption IPV and found to be significant at less than 1% probability level. A minute increase in the walking distance to the nearest plot reduces the probability of adoption of IPV by 0.7 percent. This could be because, farmers frequently visit, manage, apply organic matter and conservation practice at the nearest plot and in most case the closest plot has better soil fertility (e.g. backyard). Potato in nature needs more fertilizer, 195kg dap and 165 urea per hectare (Ketema *et al*., 2016). Potato provides high tuber yield at more fertile plots. In addition, potato needs frequent hoeing and earthing up. As a result, the proximity of the plot is a highly significant factor for adoption of improved potato varieties.

For most farming households, extension advice is the main sources of information on agricultural technologies. The result of this study indicated that, access to extension advice about improved potato varieties is significant at less than 1% probability level and increase the probability of adoption of IPV by 22.4 %. This suggested that access to extension advice helps farmer to be aware and drown interest for new technologies, and thereby to foster technology adoption. The study result is consistent with Temesgen *et al*. (2009) and Endris (2003) report.

The result of this study shows the existence of neighbor adopter positively affecting the adoption of improved potato varieties at less than 1% of probability level. The existence of neighbor adopter increases the adoption probability of IPV by 73.4 percent. This could be since, farmer learn about the new agricultural technologies and build trust on its' performance more from their neighbor. The other reason could be, the neighbors producer farmers could be

the source of seed and neighbor farmers could easily get seed. The positive association between adoption of technologies and prior extent of adoption by neighbors were reported by Foster and Rosenzweig (2010)

Farmers positive perception on the early maturity of the new potato varieties was positively affecting the adoption of the improved potato varieties. The result of this study is statically significant at less than 1% level. A positive change in perception of farmer's on earliness of the improved potato varieties increases the probability of adoption by 14.7 percent. The result in lined with Mignouna *et al*. (2011); farmers who perceive the technology being suitable with their needs and environment are likely to adopt since they find it as a positive investment.

To select or prioritize potato varieties, the yield potential is considered as the most important traits. If farmers believe that, improved potato varieties are superior in tuber yield potential than the local one, they draw a strong interest to use and adopt it. The positive perception on IPVs yield potential was positively affecting the adoption of IPVs and the result was statistically significant at 5% level. A positive change in perception of farmer's on IPVs tuber yield potential increases the probability of adoption by 10.4 percent. Akinwumi and Jojo (1995) reported positive perception on the yield was significant factor of improved sorghum varieties adoption. Endris (2003) also shows similar finding.

Table 6: Factors affecting probabilities of adoption (Tobit model result)

Variable	Coefficient	Standard error	t-statistics	Marginal effect
SEX	-0.0724061	0.0639255	-1.13	-0.052
AGE	-0.0078964	0.0051576	-1.53	-0.006
HHSIZE	-0.0100445	0.0132085	-0.76	-0.007
EDUHH	-0.0087549	0.0177784	-0.49	-0.006
FARMEXPR	0.0056841	0.0048484	1.17	0.004
TLU	-0.0053339	0.0093657	-0.57	-0.004
SIZEOFLA	0.2241152	0.0831137	2.7***	0.160
IRRACCES	0.0244149	0.0530581	0.46	0.017
CLOSERPD	-0.0104125	0.0030084	-3.46***	-0.007
EXTENSIONA	0.3131135	0.0766368	4.09***	0.224
NEIGHBOR	1.024648	0.0716863	14.29***	0.734
IPVMATURITY	0.2048729	0.0617917	3.32***	0.147
IPVYIELD	0.1458926	0.072901	2**	0.104
CONS	-0.3618573	0.1959433	-1.85*	
SIGMA	0.3815119	0.0305204		
Number of obs	370			
F (13, 357)	61.08			
Pseudo-R^2	0.6210			
Log pseudolikelihood	-146.81234			
Prob > F	0.0000			
Left-censored sbs	185			
Uncensored obs	185			

Note: ***, ** and * are significance at 1%, 5% and 10% respectively. Source: Model output

4.2.2. Effects of Changes in Explanatory Variables

The size of cultivated land was significantly, and negatively affecting the proportion of land allocated for improved potato varieties at 5% level of significance. The results of this study in table 7 indicated that, on average each additional hectare of land decrease the proportion of

areas under IPVs by 5.2 percent. The result is consistent with Gairh *et al*., (2017) report on the adoption of improved potato varieties in Nepal. Since potato needs intensive management and cultivated at smaller areas, the proportion of area under IPV are less for larger plot holders.

Access to extension advice about the improved potato varieties has a positive effect on the proportion of land allocated for improved potato varieties and the result is significant at 5% level. Access to extension advice increases the use intensity of IPV by 5.6 percent. Cerdan *et al*. (2009) indicated the positive effect extension services for the quicker technology adoption.

The existence of neighbor adopter and the proportion of area allocated for improved potato varieties were positively related and the result is significant at 1% probability level. The estimated increase in use intensity of IPV due to the existence of neighbor adopter is 18.3 percent.

Farmers positive perception on earliness of the improved potato varieties affect the proportion of areas allocated for IPPVs area allocation positively and the result is statistically significant at 1% level. A positive perception changes on IPVs maturity increase the intensity of adoption by 4.8 percent. Fufa and Rashid (2016) on their determinants of fertilizer use on maize indicated that, perception of high price reduced the use of fertilizer by 46.2kg/ha.

Table 7: Intensity of adoption and the marginal effect of explanatory variables

Variable	Change in intensity of adoption	p>z	Standard error
SEX	-0.024	0.211	0.020
AGE	-0.001	0.264	0.001
HHSIZE	-0.003	0.379	0.003
EDUHH	0.000	0.987	0.005
FARMEXPR	0.001	0.23	0.001
TLU	0.002	0.476	0.002
SIZEOFLAND	-0.052**	0.021	0.023
IRRACCES	0.002	0.845	0.013
CLOSERPD	0.000	0.484	0.001
EXTENSIONA	0.056**	0.003	0.019
NEIGHBOR	0.183***	0.000	0.018
IPVMATURITYP	0.048***	0.001	0.014
IPVYIELD	0.016	0.415	0.019

Source: Based on model output

In addition to the model result, the focus group discussion and key informant interview were conducted for in-depth analysis of improve potato varieties production constraints and its' contribution of IPVs adoption towards nutrition security. The qualitative analysis indicated that, the following important problems in improve potato varieties production.

Weak extension system and seed shortage: the woreda extension system is very week in potato production. There is no established seed system. Only NGOs with few cooperatives were the sources of seed. Due to early generation seed shortage, cooperatives are not producing and supplying quality planting materials for the last two years. Unlike the cereal's crops, the *woreda* extension did not supply quality improved potato seed. Potato needs high seed rate (1.8-2 tone of seed per hectare) and farmers have not enough seed access to cover the larger plots.

Low tuber yield potential of the late generation seed: early generation seed of improved varieties provided high tuber yield; however, the late generation seed tuber yields potential decreases from time to time and after two three years provide the tuber yield below the local variety potential. Therefore, early generation improved potato seed should continuously supply by creating linkage with seed producer cooperatives.

Potato disease: it is one of important problems which discourage farmers to engage in potato production. Due to disease problem, farmers confidence in potato production decreasing.

Poor agronomic practice: Famers in the *woreda* did not apply all recommended agronomic and management practice in potato production many farmers did not apply all the recommended packages and management practice such as row planting seed rate, hoeing and earthing up. As a result, still their production less by far from the research trials result of the same areas.

Low market price: most farmers sell their produce immediately after harvesting and the price of potato is very low during production and very high after few months of production.

4.2.3. Estimation of Propensity Scores

The logistic regression model was applied to estimate propensity score matching for Improved potato adopter and non-adopter households. In this step, propensity score matching (the probability of participation) which summarizes all independent variables information was generated to make matching on a single variable.

Table 8 indicated the pseudo-R^2 value is 0.1394 and such low pseudo-R^2 tell us the sample households do not have much difference in overall characteristics. As a result, finding a good match between IPV adopter and non-adopter could not be difficult.

Table 8:Variables used for PS generation and logit result of households IPV production participation

IPV	Coef.	Std. Err.	Z	P>z
SEX	-0.2567515	0.3238833	-0.79	0.428
AGE	-0.0287049	0.0200607	-1.43	0.152
HHSIZE	0.0859544	0.0729902	1.18	0.239
EDUHH	-0.082969	0.0944779	-0.88	0.38
FARMEXPR	-0.0219605	0.0217711	-1.01	0.313
DPNDNCYR	-0.3272836	0.1879626	-1.74	0.082*
TLU	0.0486172	0.048577	1	0.317
WMRKTDST	-0.0115354	0.0037849	-3.05	0.002**
SIZEOFLA	1.657535	0.4518785	3.67	0.000***
IRRACCES	0.5688424	0.2371758	2.4	0.016**
PLOTSWZRF	0.2613633	0.0731473	3.57	0.000***
NOFFERTIPLT	0.1005548	0.1012686	0.99	0.321
LOGOFINCM	-0.0369461	0.0730343	-0.51	0.613
CONS	0.4103187	1.01731	0.4	0.687

No. of observations = 370, LR chi2(13) = 71.48, Prob > chi2 = 0.0000, Pseudo R^2 = 0.1394
Log likelihood = -220.72557

Figure 2 below shows, the sample treated, and control households estimated propensity score distributions. The propensity score for most treated households is found in the right side of the distribution and partly in the middle, whereas for control households more of it is found at the left side of the distribution and partly in the middle of the distribution.

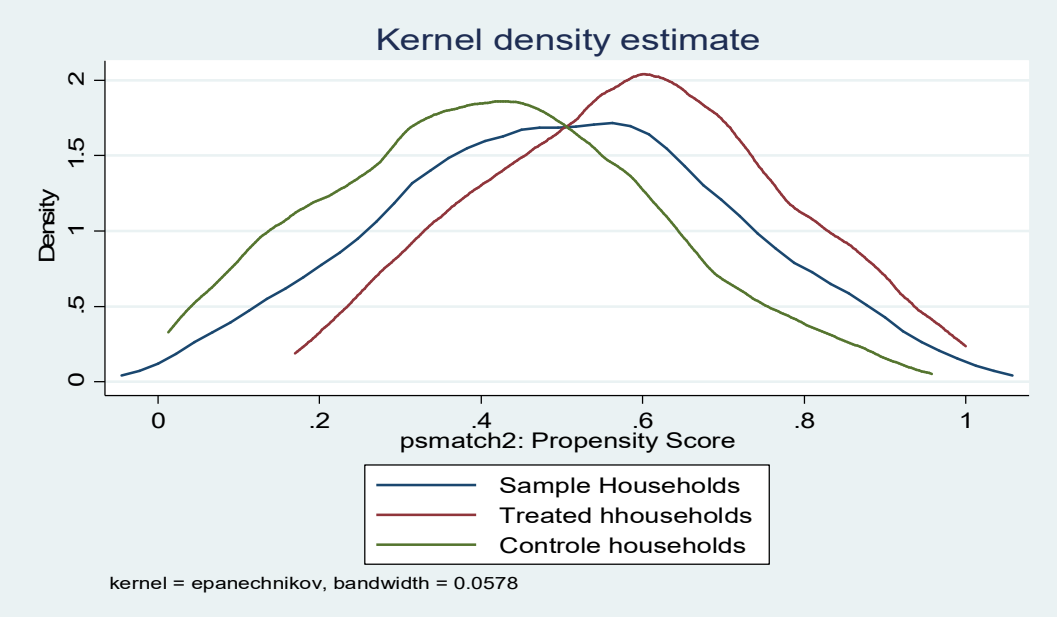

Figure 3: Kernel density of propensity score distribution before matching

4.2.4 Matching Improve Potato Adopter with Non-Adopter Households

As indicated in table 9 below, the propensity distribution for sample household is 0.0126956 and 0.9997798. The propensity score varies between 0.1697312 and 0.9997798 for improve potato adopter and, between 0.0126956 and 0.9578436 for non-adopter households. Based on the 'minima and maxima criterion' the common support region lies between 0.1697312 and 0.9578436. Households which lie outside this region are discarded from analysis and because of this restriction, 26 control and 3 treated households were excluded from analysis.

Table 9: Distribution of estimated propensity score

Sample	Observation	Mean	STD	Min	Max
All Household	370	0.5	0.2095917	0.0126956	0.9997798
IPV adopter	185	0.5876143	0.1842343	0.1697312	0.9997798
IPV Non-adopter	185	0.4123857	0.1967685	0.0126956	0.9578436

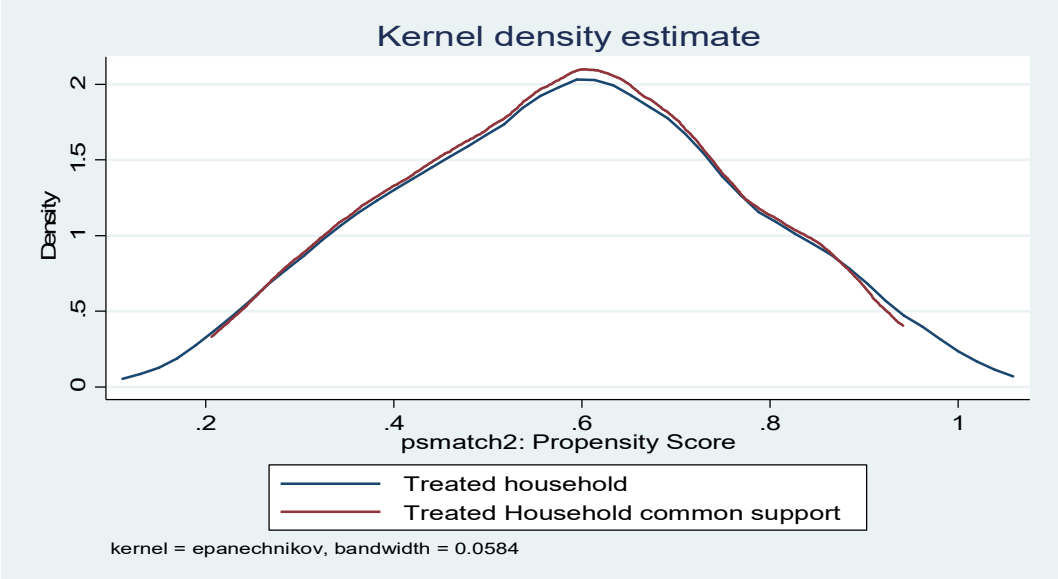

Figure 4**:** Kernel density of propensity scores of treated households

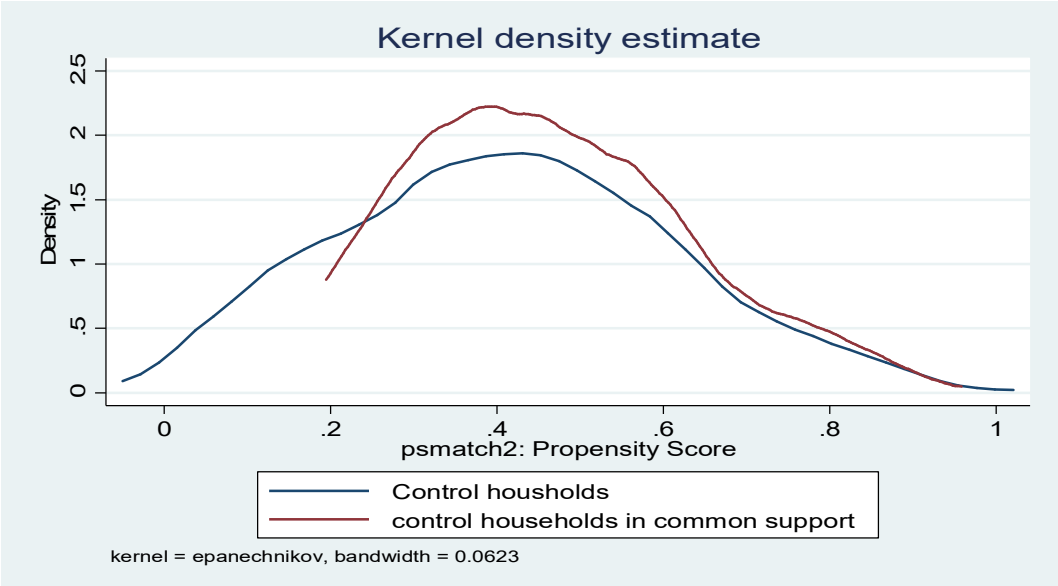

Figure 5: Kernel density of propensity scores of control households.

As indicated in table 10 the performance of different matching estimators, the balancing test and pseudo-R^2 is the same for all matching estimator. The matched sample size is 341, except caliper 0.01 and Kernel (bw 0.01) which is 322.

Table 10: Performance of different matching estimator

Performance criterion				
Matching Estimator	Balancing test	Pseudo-R^2	Matched sample size	PS-test result & No. of unbalanced variables
Caliper				
caliper 0.01	10	0.1394	322	2
caliper 0.05	10	0.1394	341	3
Caliper 0.25	10	0.1394	341	3
caliper 0.5	10	0.1394	341	3
Kernel				
Kernel (bw 0.01)	10	0.1394	322	0
Kernel (bw 0.25)	10	0.1394	341	1
Kernel (bw 0.5)	10	0.1394	341	4
Nearest neighbor				
Nearest Neighbor 1	10	0.1394	341	3
Nearest Neighbor 2	10	0.1394	341	1
Nearest Neighbor 3	10	0.1394	341	0
Nearest Neighbor 4	10	0.1394	341	0
Nearest Neighbor 5	10	0.1394	341	0
Radius				
Radius 0.01	10	0.1394	341	6
Radius 0.25	10	0.1394	341	6
Radius 0.5	10	0.1394	341	6

To know whether matching estimators adequately balance all explanatory variables or not, propensity score and covariance test were applied for all the above matching algorism. The ps-ttest result clearly shows the nearest neighbor (NN 3, NN 4 and NN 5) and Kernel (bw 0.01) matching methods adequately balance all explanatory variables. However, the matched sample size for kernel (bw 0.01) matching method is smaller than the nearest neighbor methods. Therefore, the final choice was made among the nearest neighbor matching algorisms considering the Chi-square test for the joint significance of variables (Table 12).

The PS and covariates balance test using the nearest neighbor matching estimator (neighbor (3)) in table 11 indicated that, before matching the mean of household size, education and off farm income are significantly different, however after matching there is no statistically significance mean difference between covariates of control and treated group.

Table 11: Propensity score and covariance balancing test

Variable	Sample	Mean		%bias	%bias reduction	T-test	
		Treated	control			T	P>/t/
PSCORE	Unmatched	0.58761	0.58678	0.4		0.04	0.965
	Matched	0.58106	0.57848	1.4	-250	0.14	0.889
SEX	Unmatched	0.81081	0.78378	6.7		0.65	0.519
	Matched	0.80769	0.80769	0	100	0	1
AGE	Unmatched	43.032	43.157	-1		-0.1	0.922
	Matched	43.192	43.416	-1.8	-80	-0.18	0.858
HHSIZE	Unmatched	5.8432	5.427	21.5		2.11***	0.035
	Matched	5.8352	5.6172	11.3	47.44	1.08	0.28
EDUHH	Unmatched	2.4324	2.9243	-32.7		-2.94***	0.003
	Matched	2.4231	2.5055	-5.5	83.2	-0.5	0.618
FARMEXPR	Unmatched	21.243	20.892	2.9		0.28	0.776
	Matched	21.313	21.346	-0.3	89.6	-0.03	0.979
DPNDNCYR	Unmatched	0.89108	0.88233	1.2		0.13	0.898
	Matched	0.88516	0.83076	7.5	-525	0.84	0.399
TLU	Unmatched	3.7096	3.9685	-9.5		-0.81	0.421
	Matched	3.6663	3.6546	0.4	95.8	0.04	0.969
WMRKTDST	Unmatched	43.362	42.768	1.8		0.2	0.838
	Matched	43.473	42.315	3.5	-94.44	0.4	0.69
SIZEOFLA	Unmatched	0.83937	0.81655	5.3		0.46	0.644
	Matched	0.80032	0.77953	4.9	7.55	0.57	0.569
IRRACCES	Unmatched	0.66486	0.70811	-8.9		-0.9	0.371
	Matched	0.65934	0.69963	-8.3	6.74	-0.82	0.412
PLOTSWZRF	Unmatched	2.4486	2.6162	-9.8		-0.89	0.375
	Matched	2.4341	2.3755	3.4	65.3	0.31	0.758
NOFFERTIP	Unmatched	1.6216	1.6486	-2.1		-0.19	0.846
	Matched	1.5879	1.685	-7.7	266.6	-0.69	0.488
LOGOFINCM	Unmatched	7.849	8.4389	-34.2		-3.36***	0.001
	Matched	7.8386	7.8453	-0.4	98.8	-0.04	0.97

Among matching estimators which balanced all covaries, nearest neighbor (3) in the chi-square test (table 12) provided the lowest pseudo $-R^2$ and LR χ^2, and the highest chi-square. The low R^2 indicates the absence of systematic differences in the distribution of covariates between treated and control groups (Caliendo and Kopeinig, 2005). The chi-square test result bellow shows, the distribution of mean of covariates was significantly different before matching; but after matching the distribution is the same (no significant difference). All the above tests result confirmed nearest neighbor (3) matching estimator is relatively the best matching methods and could be used to calculate the average treatment effect improved potato varieties on FSS, FCS and HDD welfare outcomes.

Table 12: Chi-square test for the joint significance of variables

Matching methods	Sample	Pseudo R^2	LR χ^2	p>χ^2
	Unmatched	0.052	26.62	0.022
Nearest neighbor 3	Matched	0.009	4.46	0.992
Nearest neighbor 4	Matched	0.011	5.57	0.976
Nearest neighbor 5	Matched	0.011	5.38	0.980

4.2.5. Average Treatment Effect on the Treated (ATT)

This section provides evidence on the impact of improved potato varieties on households' dietary diversity, food consumption and food security welfare outcomes.

Accordingly, the average treatment effect (ATT) calculated by applying PSM with nearest neighbor (3) matching method is presented in table 13. Based on the model result, the effect of IPVs adoption on the households FSS was 1.79 points on average. This indicates, the average treatment effect on adopter households is 1.79 less points in FSS compared to the non-adopter households with similar covariates. The FSS difference between the two groups of households was negative and statistically significant at 1% level. The negative ATT on FSS indicated that, the higher and lower food insecurity scale value for non-adopter and adopter households respectively. This result is in lined with Victor *et al*. (2016) findings on the Effect of the improved sweet potato varieties on household food security.

The other nutrition status indicator is the households' food consumption score, which measure the quantity, the diversity and relative nutritional importance of the household's food. The PSM model result indicated, the average treatment effect on the households' FCS 6.65. The positive value of ATT shows, the treatment effect on adopter households are higher than their counterfactual non-adopters. The FCS difference between adopter and non-adopter groups is statistically significant at 1% level.

The third important variable to measure the nutritional status of the households' is the household dietary diversity score. The average effects of IPVs adoption on HDDS is 0.86 points. The positive ATT value indicated treatment effect was higher for adopter households than similar non-adopter households and the difference is statistically significant at 1 % probability level.

Table 13: ATT estimation result of households' food security scale, dietary diversity score and food consumption score

Outcome variable	Treated	Control	Difference
FSS	1.823	3.618	-1.795*** (0.128)
FCS	47.956	41.306	6.649***(1.757)
HDDS	5.622	4.759	0.863***(0.186)

Note: **** is significance at 1% and standard errors are given in the parenthesis

4.2.7. Sensitivity analysis of ATT estimation

Here the basic question to be answered is, whether the estimation of the treatment effects are affected by unobserved factors or not. Thus, to answer this question sensitivity analysis was conducted for food security scale, food consumption score and households' dietary diversity and outcome variables.

Table 14 presents the critical level of e^r (first row), at which the causal inference of significant improved potato varieties adoption effect must be questioned. The values in each row corresponding from e^r=1 to e^r =2 are p-critical values (or the upper bound of Wilcoxon

significance level -Sig+). The sensitivity analysis result indicated that, estimation of the impacts of improved potato varieties adoption does not alter, even if the treated and control households were allowed to differ in their odds of being treated up to 100% (e^r=2) in terms of unobserved covariates. Meaning the estimation of household food security scale dietary, diversity and food consumption score at various level of critical value of e^r, the p- critical values are significant. This further indicated, we have considered all important covariates that affected both participation and outcome variables. As a result, we could conclude that, the impact estimates (ATT) of FSS, FCS and HDD are insensitive to unobserved selection bias and are the pure effect of improved potato adoption.

Table 14: Result of sensitivity analysis using Rosenbaum approach

Outcomes	e^r=1	e^r= 1.1	e^r= 1.2	e^r= 1.3	e^r= 1.3	e^r= 1.4	e^r= 1.5	e^r= 1.6	e^r= 1.7	e^r= 1.8	e^r= 1.9	e^r=2
FSS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FCS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.1e-16
HDD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

4.2.7. Endogenous Switching Regression Model Result

As presented in table 15 below male headed households has a significant and positive correlation with FCS and HDDSs for participant farmers only. The result justifies, male-headed households could participate in labour-intensive income generating activities and earn better to diversify their food.

The household size negative correlated with FCS and the correlation is significant at 5% and 1% level for adopter and non-adopter groups respectively. For adopter groups households' size was negatively corelated with HDDS at 10% significance level. This suggests the larger household size reduces the household food diversity. The result is consistent with Seng (2016) finding on Effects of market participation on farm households' food security.

The household head's education level was positively correlated with FCS and significant at 5% level. They effect are likely to be greater among adopter farmers, since the coefficient of

adopter is higher than non-adopter. The coefficient of household education was highly significantly and positively associated with HDDS for both the IPV adopter and non-adopter households. This is because, the better educated households may have better knowledge on the food diversification for nutrient adequacy. Mugisha *et al.* (2017*)* on their Factors Enhancing Household Nutrition Outcomes in Potato Value Chain study found that education level of household head has a positive and significant influence on HDDS.

Farming experience has significant and positive association with HDDS at 5% significance level for adopter groups only. Suggesting that households with higher farming experience may have better experience in diversified food crop production and consume more diversified food groups.

Dependency ration was negatively corelated with both FCS and HDDS, but the association is significant only with HDDS for non-adopter categories. The effect of dependency ration on HDDS for adopter categories is lower, suggesting household who adopt IPV enjoy higher HDDS then non-adopters.

The size of livestock owned was highly significant and negatively correlated with FSS for adopter groups. FSS is the scale the food insecurity cores, the negative association with FSS indicates the positive association with food security status. Households with greater number of livestock are the better in consuming animal products and to access cash to purchase diversified food items, suggesting adopter households with higher number of livestock enjoy lower food insecurity.

The size of livestock has also significant and positively correlation with FCS and HDDS in both groups of households. The coefficients are larger in adopter groups, indicating the effect of livestock holding size on FCS and HDDS was greater amongst IPV producer. Mugisha *et al*. (2017) found that positive and significant relationship between the size of livestock holding and HDDS.

The coefficient of landholding is significant and negative for FSS of the non-adopter households, indicates that land area has positive influences on the household food security. Land size has highly significant and positive influence on FCS. Mugisha *et al*. (2017)

reported that land size has positive and significant effect on both food security and household dietary diversity.

Access to irrigation has negatively and significantly corelated with FSS for adopter and non-adopter groups at 1% and 5% level respectively. The coefficient for adopter categories is larger, this indicates the effect of irrigation is greater for the adopter group. Access to irrigation further has highly significant and positive correlation with FCS and HDDS for adopter households. For both FCS and HDDS coefficients are much larger for adopter categories, which further shows the effect of irrigation greater for adopter households. This is mainly because irrigation helps farmers to produce crops more than per years and to produce cash crops, which in turn helps to purchase other food groups and diversify their diet.

Number of plots with recommended rate of fertilizer rate and FSS corelated negatively and significantly for non-adopter households. Application of recommended fertilizer increases farmers production and could reduce the amount of cash spend to purchase similar crops and households could purchase other food groups with cash from different sources. The number of fertile plot that the households were cultivating and FSS positive correlation. The association is significant at 10% and 1% respectively for adopter and non-adopter groups. Similarly, there is a positive and significant correlation at 10% level between number of plots fertile plots and FSC of non-adopter categories.

Amount of off-farm income earned and FSS has highly significant and negative association for non-adopter households, suggesting households with higher amount of off-income are likely to enjoy better household food security. The amount of off-farm income also positively corelated with FCS of non-adopter group and HDDS at 10% and 5% level respectively.

Table 15: Determinants of nutrition security status (second stage)

Variables	FSS 1	FSS2	FCS1	FCS2	HDDS1	HDDS2
Sex	-0.184	0.245	7.316**	2.216	0.415*	-0.078
	(0.22)	(0.19)	(3.15)	(2.15)	(0.25)	(0.23)
Age	-0.001	0.013	-0.068	-0.108	-0.021	0.013
	(0.01)	(0.01)	(0.17)	(0.13)	(0.02)	(0.02)
HHsize	0.031	0.037	-1.478**	-1.888***	-0.121*	-0.072
	(0.04)	(0.05)	(0.73)	(0.43)	(0.07)	(0.05)
EduHH	-0.066	-0.054	1.869**	1.478**	0.324***	0.336***
	(0.05)	(0.06)	(0.81)	(0.71)	(0.07)	(0.08)
Farmexpr	0.008	-0.011	0.037	0.036	0.037**	-0.010
	0.01 ()	(0.01)	(0.20)	(0.12)	(0.02)	(0.02)
Dpndncyr	0.079	0.056	-2.222	-0.339	-0.091	-0.249**
	(0.12)	(0.09)	(1.99)	(0.98)	(0.19)	(0.11)
TLU	-0.085***	-0.056	0.870**	0.740**	0.200***	0.094**
	(0.02)	(0.04)	(0.37)	(0.32)	(0.03)	(0.04)
Wmrktdst	0.00	-0.002	-0.017	-0.009	0.002	0.000
	(0.001)	(0.00)	(0.04)	(0.03)	(0.00)	(0.00)
Sizeofland	0.21	-0.820**	2.393	11.008***	0.118	-0.221
	(0.310)	(0.33)	(2.22)	(3.24)	(0.24)	(0.34)
Irracces	-0.342***	-0.329**	5.545***	0.413	0.664***	0.274
	(0.14)	(0.16)	(2.13)	(1.71)	(0.19)	(0.19)
Plotswzr	-0.041	-0.099**	-0.876	-0.078	-0.020	0.060
	(0.04)	(0.04)	(0.60)	(0.61)	(0.06)	(0.07)
NofFerti	-0.089*	-.139***	1.334	1.440*	0.084	-0.013
	(0.05)	(0.05)	(0.87)	(0.84)	(0.09)	(0.08)
Logofincm	-0.049	-0.131***	0.729	1.087*	0.125**	0.088
	(0.04)	(0.04)	(0.59)	(0.63)	(0.05)	(0.07)
mills1	-0.049	-0.162	-0.742	-0.947	0.094	0.351
	(0.10)	(0.36)	(1.56)	(5.49)	(0.13)	(0.44)
Cons	3.260***	5.633***	37.040***	28.250***	2.946***	3.105***
	(0.51)	(0.56)	(9.23)	(7.14)	(0.88)	(0.77)
R2	0.2491	0.2609	0.2454	0.2567	0.4146	4.37
F (14,170)	4.38	7.69	4.97	8.10	11.38	0.2271

Note: ***, **, * are significant at 1%, 5% and 10% level; and 1& 2 with dependent variables represent regime 1 and 2 respectively. Standard errors are given in the parenthesis.

4.2.7.1. Nutritional Impacts of Improved Potato Varieties Adoption

In this sub section the most important question is whether households that adopt IPVs are better in terms of nutrition security using proxy indicator variables (FSS, FCS and HDDS).

To complement the propensity score matching model and assess consistency of the results with different assumptions, ESR model was applied and the model results were presented in table 16. The table shows, base heterogeneity and treatment effects of IPVs adoption between the treated and control groups.

Accordingly, the observed difference (a-b) in FSS, FCS and HDDS between adopter and non-adopter households was -2.14, 10.4 and 1.1 respectively. However, compression the treatment effect without accounting unobserved factors might provide us misleading result.

Thus, to account the effect of unobserved variables on the welfare outcomes, the heterogeneity effect was considered. The heterogeneity effects gave the deference in expected households' FSS, FCS and HDDS. With the counterfactual condition that, where IPV adopters would have been non adopter, the households expected to have 0.088 higher points in FSS and, 4.67 and 0.017 less points in FCS and HDDS respectively. Similarly, were the non-adopter households would have been IPVs adopter, the households would have 0.086 and 0.37 less FSS and HDDS respectively, but 4.28 higher points in FCS. In both counter factual conditions, the IPVs adopter households have less FSS values (better in food insecure) and higher in FCS (better in food and nutrient adequacy) and HDDS (better in food diversity) than IPVs non adopter, except BH2 of HDDS. These difference shows the systematic sources of variation between IPV adopter and no-adopter which couldn't be captured only by observable variables in the model. Dorah *et al* (2015) indicated as potatoes are a reliable source of food and income since it can be eaten as a staple and sold to get income for purchasing other foodstuffs. Their finding confirmed that, potato production significantly increases household's food security.

Table 16 (column 5) presents the treatment effects of IPVs adoption between the treated and control groups as expected change in the households' food security scale, food consumption score, and food diversity score values. The mean effects of the treatment (ATT) for adopter households was less of 2.05 in FSS and higher by 6.13 and 1.48 points in FCS and HDDS respectively compared to their counterfactuals. Similarly, IPVs non-adopter were placed into the status of adopter, their FSS would be less of 2.0485 and their FCS and HDDS would be increase of 5.745 and 1.099 points respectively. The result of this study is consistent with

other prior studies. Abadi (2018) found the positive and significant effect of adoption of sweet potato on household's food consumption and similarly Kilui (2016) reported the positive effect of adoption of improved sweet potato varieties on household's dietary diversity.

The transitional heterogeneity effect is positive for FCS and HDDS, and negative for FSS outcome variables, meaning IPVs adoption effect is higher for adopter households. The ESR model result indicated that, the difference in the mean value of food consumption score and households' dietary diversity score between the improved potato adopter and non-adopter households were positive, whereas the difference in the mean value of FSS was negative. Statistically, these were found to be significant at 1% significance level. The result consistence with Mugisha et al. (2017).

The focus group discussion confirmed indicated that, improved potato varieties provided very high tuber yield from smaller plot of land (up to 5 time higher as compared to the cereals) and mature at critical food shortage periods. Income from the sale of potato helps households to purchase diversified food items. Potato producer consume potato from their plot by using delayed harvesting storage mechanisms usually in the form of sauce for adults and both in the forms of sauce and boiled for children's. Potato producer farmers had better in consuming potato and other vegetables than the non-producer households. Thus, FDG result confirmed the econometric model result that is IPVs producer had better nutrition status as compared to the non-producer.

Table 16: Expected conditional and average treatment effect of IPV on dietary diversity, food consumption, and food security of the household.

Outcome variables	Categories	Decision stage		Adoption effect
		IPV adopter	IPV non-adopter	
FSS	ATT	(a1) 1.816554	(c1) 3.867359	-2.050805***
	ATU	(d1) 1.904563	(b1) 3.953113	-2.04855***
	HE	BH1= -0.088009	BH2= -0.085754	-0.002255
FCS	ATT	(a2) 48.30567	(c2) 42.1734	6.132272***
	ATU	(d2) 43.63308	(b2) 37.88787	5.745205***
	HE	BH1= 4.67259	BH2= 4.28553	0.387067
HDDS	ATT	(a3) 5.645625	(c3) 4.161348	1.484277***
	ATU	(d3) 5.628297	(b3) 4.529423	1.098874***
	HE	BH1= 0.017328	BH2= -0.368075	0.385403

Note: BH1 = the effect of base heterogeneity for IPV user (a-d)
BH2 = the effect of base heterogeneity for IPV non-user (c-b)

5. SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary and Conclusion

Increasing population pressure, land degradation, and shrinking the land holdings necessitated intensification of production practices to meet the increasing food demand of the populations. To meet the continuous increase of food demand, there is a need to produce more food crops from the existing plot of lands using improved crop varieties and practices. In this regard, potato has multiple benefits for low income households and where land shortage is a constraint. Thus, potato plays a great role towards ensuring food and nutrition security which is a major concern for the country. In Emba Alaje woreda, few potato varieties technologies were introduced and promoted by government and non-governmental institutions. However, the rate and level of adoption, and its impact on the households' nutrition security were not analyzed. Therefore, this study aimed to identify factors affecting adoption probability and use intensity of IPV and the adoption effect IPVs on household's nutrition security.

The primary data for this study was collected from 185 IPVs grower and 185 non-grower farming households' using structured questionnaire. To complement the formal household survey, focus group discussion and key informant interview and other data from secondary source were used.

Both STATA and SPSS software packages were employed to compute the descriptive and econometrics analysis. The descriptive result indicated that, 88% of adopter and 71% of non-adopter are in medium and high household dietary diversity categories. This shows IPV increase the number of households medium and high category households by 19%. The 53.5% of non-adopter households had borderline level of food consumption, whereas 75% adopter households had an acceptable level of food consumption. About 65% of non-adopter households are food insecure without hunger, implying households' members had enough to eat which are not balanced well in nutritional content. About 60.5 % of adopter households are food secure, this is mainly because the high yielding and maturity period of improved potato varieties.

Tobit model was applied to analyzed factors affecting the adoption and use intensity of IPVs adoption, since the model has an advantage of dealing with censored observation and generating information for both adoption probability and use intensity. In Tobit model estimation 13 variables were used and among those variables, land size, nearest plot distance from the homesteads, access to extension advice, existence of neighbor adopter and perception on the IPV maturity period and tuber yield potential were found significant in influencing of adoption probability and use intensity of IPVs. In addition to the model result, the key informant interview and focus group discussion indicated that the woreda extension stem is very week in potato production. For the last two year the seed producer cooperatives were not supplying seed because of absence early generation seed for multiplications. Shortage of improved potato varieties, low tuber yield potential of late generation seeds, disease, poor agronomic practices, and low market price during production are the main problems in potato production. Famers in the woreda did not apply all recommended agronomic and management practice in potato production and still their production less by far from the research trials result of the same areas.

To estimate the effects of IPVs adoption, and to correct selection bias and check the consistency of the result with different assumption both propensity score model and endogenous switching regression model were used. The propensity model result shows improved potato varieties increased households' food security, food consumption and household dietary diversity significantly.

There is the presence of structural differences between the adopter and non-adopter groups; for example, landholding has positive effects on the IPV producers' households' food insecurity but negative impacts on the non-producer households' food insecurity. Similarly, farming experience has positive effects on IPV adopter farmers' HDDS and negative effect for non-adopter households' HDDS. To account the self-selection bias and systematic differences we applied endogenous switching regression model. Our ESR model result confirmed that, improved potato varieties adoption decreases the household food insecurity and increase both food consumption and the food dietary diversity significantly. This is mainly because, in the study area improved potato reach for harvesting at critical food shortage period, usually at September and October were neither the food crop at storage not

available nor matured at the filed. As a result, potato can contribute to mitigate seasonal gaps in food availability and uses as source of cash to purchase other food items to diversify and complement the available food for home consumption.

The focus group discussion similarly confirmed that, IPVs provided very high tuber yield from small plot of land and income from the sale of potato used to purchase different food items. In addition, potato producer farmers had a better habit in consuming potato and other vegetable than the non-producer farmers.

In general, our finding revealed IPV potato variety adoption improve the food security status, food consumption and dietary diversity of the households significantly. These three outcome variables provided the quantity, quality, diversity, relative importance and the behavior of the households on food security which together indicate the betterment in nutritional status.

5.2. Recommendation

Our study result indicated, participation in improved potato production has statistically significant and positive impact on household's food security, household's food consumption and household's dietary diversity, there by contributes to nutrition security. Hence, the following recommendation are forwarded households to improve their nutrition status through potato production.

The study found that, the distance of the nearest plot affects household potato production participation negatively and significantly. Since organic matter is bulky in nature to transport, in most case, households apply organic matter at the closer plot and got a good return from potato production. Therefore, we recommended households to apply recommended rate of inorganic fertilizer and produce potato including the far plots or to exchange plots for to reduce the distance from the homestead.

Our finding revealed that access to extension advice is one of the significant factor in determining the household's participation in IPV production. Thus, to improve the food and nutrition security situation, households should maximize their produce through improved potato varieties production. Therefore, government should give due emphasis for potato

production and extension service need to be strengthen since it is the main sources of information for farming households about new technologies.

Our analysis result shows, existence of neighbor adopter has a highly significant effect on potato production participation. This is because farmers learn more and build trust on the performance of the technology from their neighbor. Therefore, to enhance the adoption process research centers and extensions should promote improved varieties through participatory varieties selection trials approach to show the performance of new varieties at farmers field.

Because of the IPV high yielding and early maturity traits farmers were replaced the local variety. However, unlike the local potato variety the late generation IPV did not provide the potential yield continuously. Thus, the result of this study suggests farmers not to replace the local varieties totally with improved varieties unless the strong and efficient seed system is established.

To deal with shortage of early generation seed and potato disease problem, it is necessary to create strong linkage between research, seed producer cooperatives and farmers. Our finding suggested research institute continuously to supply disease resistance varieties and early generation planting material and, link with seed producer cooperatives for multiplication.

In the study area households usually consume potato in the form of sauce. Hence, it is important to raise farmers awareness through different capacity building activities on potato production and consumption including food demonstration.

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7. APPENDIX

Appendix 1: Scale Values and Food Status Categories for The Core Scale

Households with Children			Households without Children		
Number of Affirmative Responses (Out of 18)	Scale Value	Food Security Status Category	Number of Affirmative Responses (Out of 10)	Scale Value	Food Security Status Category[a]
0	0.0	0	0	0.0	0
1	0.7	0	1	0.9	0
2	1.6	0	2	2.0	0
3	2.3	1	3	2.8	1
4	2.8	1	4	3.6	1
5	3.3	1	5	4.3	1
6	3.8	1	6	5.0	2
7	4.3	1	7	5.7	2
8	4.7	2	8	6.5	2
9	5.2	2	9	7.5	3
10	5.6	2	10	8.2	3
11	6.0	2			
12	6.4	2			
13	6.8	3			
14	7.3	3			
15	7.8	3			
16	8.4	3			
17	9.2	3			
18	10.0	3			

Source: Price et al. (1997)

Appendix 2: Correspondence Between Scale Values and Food Security Status

	Food Security Status	
Scale Value	Code	Category
0.0 to 2.2	0	Food secure
2.3 to 4.6	1	Food insecure without hunger
4.7 to 6.7	2	Food insecure with moderate hunger
6.8 to 10.0	3	Food insecure with severe hunger

Source: Price et al. (1997)

Appendix 3: Conversion Factors Used to Estimate Tropical Livestock Unit (TLU)

Types of Animals (spices)	Indigenous Breed Live weight (Kg)	TLU	Crosse breed Live weight	TLU
Cow	250	1.0	380	1.5
Heifer	125	0.5	150	0.6
Oxen (Young bull)	250	1.0	300	1.2
Calves	50	0.2	50	0.2
Sheep and goat	22	0.1		
Horse and Mule	200	0.8		
Donkey	90	0.4		

Source: Varvikko (1991)

Questionnaire

BAHIR DAR UNIVERSITY

DEPARTMENT OF AGRICULITURAL ECONOMICS

Part One: The questionnaire is prepared to study the Adoption of improved potato varieties and its household nutrition: the case of Emba Alaje Woreda, Northern Ethiopia. The purpose of this questionnaire is to gather information on household and plot level information to analyze factors of adoption and measure its nutritional impact. The study findings would be used policymaker, extension, researchers, NGOs, farmers and potato seed producer cooperatives to design appropriate strategies and enhance the potential benefits from potato production and utilization. Personal responses of interviewees would be kept confidential. Thus, you are kindly requested to give reliable information as much as possible.

1. General Information

Name of enumerator	
Date of interview and time	
District	
Kebele	
Sub kebele	
Household ID	
Name of supervisor	

2. Household head information

2.1.	Name household head	
2.2.	Sex household head	1= male, 2= female
2.3.	Age of household head in years (nearest)	
2.4.	Education status of household head	1= illiterate, 2 = read and write, 3= primary (1-4), 4, Junior (5-8), 5 = Secondary (9-10), 6= tertiary (>10 and above)
2.5.	Marital status	1= married, 2= single, 3= widowed, 4= divorced, 5= other
2.6.	Religion	1= Cristian, 2= Muslim, 3= traditional, 4=other
2.7.	Social responsibility (in the Kebele)	

3. Household members information

Start with her/his spouse, children (ranked from old to young) and lastly other household members – include only members who live with the household sharing the same Household resources at least for the last 3 months.

3.1.	3.2. Number of family members			
Name of the HH members	Sex	Age in years	Education (in years) use the above option	Relationship to the HH head (use code 1)

Code 1: 1=household head, 2=spouse, 3=son/daughter, 4=son-in-law/daughter-in-law, 5=grandson/granddaughter, 6=father/mother of head or spouse, 7=brother/sister of head/spouse, 8=other relative of head/spouse, 9=adopted, 10=non-relative/hired, 11=other (specify)

4. Infrastructure and services

Indicate the distance to infrastructure and services from the residence (walking time and distance in km)

4.1. Infrastructure type	4.2. One-way walking (in minutes)	4.3. Usually used mode of transport (**use code 2**)	4.4. Frequency of travel services/purposive contacts last year
Farmers' training center			
Development agent's office			
Microfinance institution			
All weather road			
Seasonal road			
Local (PA) Market			
Local district/woreda market			
Large Urban (Zonal) Market			
Nearest cooperative office/ shop			
Community water point			

Other (specify)			

Code 2: 1= On Foot, 2= Donkey, 3= Horse cart, 4= Foot and vehicle, 5= Vehicle, 6=bicycle, 7=other (specify)

5. Farm characteristics

5.1. Farming experience of household head: _____ years

5.2. Total size of cultivated land own _____timad _____owned in timad

5.3. Total size of uncultivated land owned-_____Timad

5.4.	Cultivated Land holding size in Timad										
Plot No	The size of the plot ?	Ownership type **(use code 3**)	Soil type, 1=clay 2=silt 3=sandy ,	Slop of the plot? 1= flat 2= steep 3= steeper	Soil fertility 1= fertile 2= medium fertile 3= less fertile	Distance from the home stead in minutes?	Access to irrigation ? 1= Yes 0= No	Crop grown in 2009/10 (**Use code 4)**	Fertilizer applied in 2009/10 ? **Code 5**	Varieties planted in 2009/10? 1= improved, 2= local	Land rental value/year/timad in Birr?

Code 3: (1= own owned, 2= share cropped in, 3= share cropped out, 4=rented in, 5= rented out 6= inherited)

Code 4: (1= wheat, 2=barley, 3= Fab, 4= F.pea 5. Lentil 6. potato, 7= linseed, 8=Teff, 9= onion, 10=Garlic, 11=tomato, 12= Cabbage, 13=green pepper, 14= Carrot, 15= other (specify)

Code 5: (1= Urea, 2=DAP, 3=Urea+DAP, 4= Manure, 5=Compost, 6= other (specify)

6. Crop production and land scape in 2009/2010

6.1.		Land preparation, planting and seed used											
Plot No	Crop type (code4)	Land preparation				Planting and seed used							
		Types of land preparation? **Use Code 6**	No of person per day?	Average payment per day?	Gender involved in land preparation? Use **Code 7**	Qtt seed used/plot?	Size of the tuber if it is potato? Use **Code 8**	Price per quintal	Types of labor? **Use Code 9**	Gender involved? Use **Code 7**	No of person/plot?	Average payment/day?	Planting time (month)

Code 6: (1. Using animal, 2. Using manual, 3. Using tractor), **Code 7**: (1. Male, 2. Female, 3. Male and female, 4. All members), **Code 8**: (1. Small, 2. Medium, 3. Large), **Code 9**: (1. Family, 2. Hired permanent, 3. causal labor).

6.1.	Fertilizer application								
Plot number	Crop type (code4)	Fertilizer and manure application							
		Do you apply fertilizer? 1=yes 0= no	Do you follow the recommended rate? 1= yes, 0= no	types of fertilizer applied? 1= Urea 2= DAP 3= Urea+DAP, 4= other (specify)	Qtt of fertilizer/plot in kg ?	Cost of fertilizer application/plot in birr?	Qtt of manure applied in Quintal?	Price in quintal if purchased?	Cost of manure application (labor) in birr

6.2.	Weeding and Earthing up							
Plot No	Crop type (code4)	Type of weeding labor? **(Code 9)**	Number of person per/plot for weeding?	Frequency of weeding?	Average payment per day in birr for weeding?	Frequency of hoeing?	Frequency of Earthing up	Total cost of hoeing end earthing up?

Cod 9: (1. Family, 2. Hired permanent, 3. causal labor)

6.3.	Use of chemical and harvesting in 2009/10												
Plot No	Crop type (code 4)	Use of chemical				Harvesting							
		Do you apply chemicals? 1= Yes, 2= No	Quantity used in litter?	Price per litter?	Cost of chemical application (labor and material)?	Types of labor used? **Code 9**	Gender involved? **Code 7**	No of days per plot	Number of person per plot?	Average payment per day?	Packaging cost per plot?	Trashing cost /plot?	Time of harvesting (month)

Code 9:(1=Family, 2= Hired permanent, 3. Causal),

Code 7: (1= Male, 2=Female, 3= Children, 4= Male and female, 5= All members)

7. Marketing related questions

7.1.	Post-harvest management and marketing of crops in 2010											
Plot No	Crop type **(Code 4)**	Total Qtt produced in quintal? In 2010	Transportation cost from farm to home ?	Storage facilities used? 1=sac,2=godo, gotera 3other	For how long you stored the produce ? In monz	Amount consumed at home in 2010?	In what form you usually consumed in 2010? **Code 10**	Amount loss through post-harvest in kg in 2010?	Amount of grain/ ware potato sold to the market in quintal in 2010?	Grain/ ware Price per quintal in birr in 2010?	Amount of seed sold in quintal in 2010?	Price of seed in quintal in 2010?

Code 10:(1=Roosted, 2=boiled, 3= Souce, 4= Enjera, 5=bread, 6= porage, 7=beso, 8= other (specify)

8. Livestock holding in 2009/10EC

Animal Type	Stock in 2009	Current stock/2010?	Born in 2009/10?	Died in 2009/10?	Slaughtered in 2009/10?	Bought in 2009/10?	Sold in 2009/10?	Average price?	Months in milking in 2009/10?	Average Milk yield per day in litter in 2009/10?	Number of egg/Kg of honey produced in 2009/10?
Milk cow											
Local											
Improved											
Oxen											
Local											
Improved											
Heifer											
Local											
Improved											
Bull											
Local											
Improved											
Calves											
Local											
Improved											

Sheep											
Goat											
Donkey											
Mule											
Horse											
Poultry											
Local											
Improved											
Beehives											
Tradition											
Transitional											
Modern											

8.2. Marketing of animal products in 2009/2010				
Animal product type	Quantity Purchased?	Purchasing price?	Quantity sold?	Selling price?
Milk (litter)				
Butter (KG)				
Honey (KG)				
Meat (KG)				
Egg (number)				
Skin (Number)				

9. Use of Improved Potato Varieties

9.1. Have you ever used improved potato variety? 1. Yes, 0. No

9.2. If yes, when did you start using? _____ year E.C

9.3. Have you produced improved potato varieties for the last one years? 1. Yes, 0. No,

94. If no for 9.3, what was the reasons?

1. _____
2. _____

3. _____
4. _____

9.5. Have you produced local potato varieties for the last one years? 1. Yes, 0. No

9.6. If no for 5.5, what was the reasons?

1. _____
2. _____
3. _____
4. _____

If yes for 9.3 and 9.5, please fill the detail below for the 2009/10 E.C main cropping season.

9.7. Potato varieties grown in 2009/10, 1.Gudene, 2. Jalene, 3. Belete, 4. Local 5. othe (specify)	
9.8. Why did you select this/se variety/ies? 1. _____ 2. _____ 3. _____	
9.9. Do you think that the improved potato variety is better than local variety in terms of the following characteristics/ traits?	
A. Yield, 1. Yes, 2. No	
B. Color, 1. Yes, 2. No	
C. Taste 1. Yes, 2. No	
D. Drought resistance 1. Yes, 2. No	
E. Maturity period, 1. Yes, 2. No	
F. Establishment ability, 1. Yes, 2. No	
G. Shelf life, 1. Yes, 2. No	
H. Resistance to diseases/pests/weeds, 1. Yes, 2. No	
9.10. Give priority order of the above traits you consider most important 1. _____ 2. _____ 3. _____ 4. _____	
9.11. From where did you get improved potato planting material? 1. BOA, 2. Research center, 3. Seed producer cooperatives, 4. Own, 5. Neighbors, 6. NGO, 7. Other, specify	
9.12. Do you think that there is risk associated to the use of new potato varieties? 1. Yes, 2. No	

9.13. If yes, what are the risks associated to the use of new potato varieties 1. _____ 2. _____ 3. _____ 4. _____	
9.14. Do you plant potato in row? 1. Yes, 0. No	
9.15. Do you use regular spacing for planting potato? 1. Yes, 0. No	
9.16. If yes for 9.15, what was the spacing (b/n row and b/n plant)	
9.17. Do you have neighbor farmers who grow improved potato varieties in 2009/10?	

10. Research and Extension services

10.1. Did you participate in on-farm research/demonstration? 1. Yes, 0. No

10.2. If yes, how many times you participated? _____

10.3. Do you participate in field day? 1. Yes, 0. No

10.4. If yes for 10.3, how many times you participated? _____

10.5. Home distance to the research center in walking hours? _____

10.6. Did you get extension advice/training on potato production? 1. Yes, 0. No

10.7. If yes, the number of training you participated? _____

10.8. If yes for 10.6, does the training include practical demonstration? 1. Yes, 0. No

10.9. What are the areas of training you participated? 1. _____ 2. _____3._____

11. Credit related questions

11.1 Have you received credit in 2009/10? 1= yes, 0=No	
If yes for Q 11.1 which category? 1= cash, 2= Kind	
What are the source of credit? **Code 11**	
If No for Q 11.1 what was the reason? **Code 12**	
What was the purposes of the credit? **Code 13**	
What was the maximum amount of credit you received?	
The interest rate of the credit was?	

The repayment duration?	
The repayment schedules? **Code 14**	
What are the main constraints to obtain credit? 1. _____ 2._____ 3. _____ 4_____	

Code 11: 1= Bank/rural banks, 2=Microfinance institutions, 3=Farmers Group, 4=Relative/Friend (non-group member), 5=Employer/wholesaler, 7=Association/equib, 8=NGOs, 9=other (specify)

Code 12: 1=the household did not have demand for extra cash, 2= loan institution need collateral asset, 3=the household didn't apply for loan because of fear failure of repayment,4= the group collateral system, groups are responsible to pay their members dept, 5= high interest rate 6=the household didn't know there were credit service possibilities around, 7=other, (Specify)

Code 13: 1= For farm input purchase, 2= For purchase of animal for production, 3= purchase of oxen for ploughing, 4= for consumption, for trading, 5= health expense.

Code 14: 1= Twice a year for the loan duration, 2=once a year (after harvest) for the loan duration, 3=At once in the repayment duration, 4=other, (specify)

11. Other Income and expenditure

11.1. Off-farm income in 2009/2010

Activity	Quantity/no. days	Income/wage/day	Net income in birr
Daily labor			
Petty trade			
crop			
Animal			
Drink			
Food			
Other (specify			
Handicraft			

Sale of natural product			
Grass			
Wood			
Charcoal			
Rent			
Land			
Oxen			
House			
Cash as aid frequency/year			
Compensation			
Remittance frequency/year			
Gift			
Others, specify			

11.2. Expenditure in birr in 2009/2010

11.2.1. Annual food consumption expenditure

Consumption items	Own Production in Quintal		Purchased in quintal		Aid in quintal		Gift in quintal	
	Amount	Price	Amount	Price	Amount	Price	Amount	Price
Cereals								
wheat								
barley								
Maize								
Tef								
Sorghum								
Rice								
Pulses								
Bean								
Peas								
Chickpea								
Lentil								

Oilseeds								
Noug								
Linseed								
Safflower								
Horticultural								
Fruit								
Vegetable								
Tuber and root crops								
Hot drinks								
Coffee (Cup?								
Tea (Cup)								
Consumption items	Own Production in kg	Purchased in kg	Aid in kg	Gift in kg				
	Amount	Price	Amount	Price	Amount	Price	Amount	Price
Cooking additives								
Oil (litter)								
Pepper (Kg)								
Spice (KG)								
Energy source								
Fire wood								
Kerosene								
Dung and other (specify)								

11.2.2. Expenditure other than food

Item	Annual consumption Total value (Birr)
Clothes	
Own (household head)	
spouse's clothes	
Children's clothes	
Service fees	
Education/school	
Human Health	

Item	Annual consumption Total value (Birr)
Telephone	
Electric	
Other (specify)	
Tax and other payment	
Land tax	
Land rent	
Property tax	
Land lease	
Other fees/contributions	
Social events (wedding, mourning etc)	
Implements /equipment	
Farm inputs	
Farm equipment	
Household equipment	
Others	
Refreshments (soft and alcoholic drinks etc.)	
Detergents	
Other (specify)	

11. **Household dietary diversity (HDD) score questionnaire**

11.1. For the following food groups, please put 1 if any member of the household consumes any food items, if not put 0 within **24 hours periods** of time.

NO	Food Group	Food Item	0=No 1= Yes
1	Cereals	Any foods made from wheat, teff, sorghum, and maize, Barely, e.g. Beso, Kolo, porridge, enjera or other locally available grains.	
2	White root and tuber	Any potatoes, or any other foods made from roots or tubers?	
3	Vegetables	Any vegetables? (Pumpkin, carrot, squash, carrot, onion, tomato, cabbage, head cabbage, lettuce, + other locally available vitamin A rich vegetables).	
4	Fruits	Any fruits? (Mango, papaya, Avocado, Apple, wild fruits and 100% fruit juice made from these + other locally available vitamin A rich fruits.	
5	Meat	Any beef, lamb, goat, wild game, chicken, duck, or other birds, liver, kidney, heart, or other organ meats?	
6	Egg	Any eggs? (eggs from chicken, duck, guinea fowl or any other egg)	
7	Fish and other sea food	Any fresh or dried fish or shellfish?	

8	Legumes, nuts and seeds	Any foods made from Beans, peas, lentil, cowpeas, pigeon peas nuts, haricot bean, chickpea, vetch?	
9	Milk and milk products	Any cheese, yogurt, milk, or other milk products?	
10	Oils and fats	Any food made with oil, fat, or butter	
11	Sweets	Any sugar, honey, sweetened soda or sweetened juice drinks, sugary foods such as chocolates, candies, cookies and cakes?	
12	Spices, condiments and beverages	Any other foods, such as condiments, salt, spice, coffee, tea, ginger, carmine, and other alcoholic beverage?	

12. Household food consumption questionnaire

12.1. Please ask whether any of the household member consumed the following food items of each groups and tick the number of days they consumed, please put 7 if the sum of the frequency the food items of the same food group are more than 7.

No	Food Groups	Food items	How many days in the past **one week** your household has eaten							
			Not eat	1	2	3	4	5	6	7
1	Main staples	Any foods from wheat, barley, maize, rice, sorghum, teff, millet, pasta, and other cereals?								
		Any food from potatoes and sweet potatoes, other tubers?								
2	Pulses	Any foods of Beans, Peas, groundnuts, lentils haricot beans and others?								
3	Vegetables	Any foods of Vegetables leaves and others?								
4	Fruits	Any Fruits? (Apple, mango, papaya, avocado, wild fruits and others)								
5	Meat and fish	Any Beef, goat, sheep, poultry, eggs and fish?								
6	Milk and mik product	Any Milk yogurt and other diary								
7	Sugar	Any sugar and sugar products, honey?								
8	Oil	Any oils, fats and butter?								
9	Condiments	Spices, tea, coffee, salt, fish powder, small amounts of milk for tea.								

13. Household food security scale

13.1. For the following food security/insecurity questions, please put the appropriate responses at the code column. To avoid asking the full set of questions use **First level screening**: If the response to Q1 is option "1 or 2" and "never true" for Q2-Q6, questions Q7-Q16 will be omitted. And the **second level screening**: If for the HH not screened previously and their response to Q7 is "never" true and "No" for Q8 to Q11, Questions Q12-Q16 will be omitted.

No	Questions	Response options	Code
1	Which of these statements best describes the food eaten in your household in the last 12 months?	1. we always have enough to eat and the kinds of food we want 2. we have enough to eat but not always the kinds of food we want 3. Sometimes we don't have enough to eat 4. Often we don't have enough to eat?	
1a	If sometimes or often not enough to eat, please tell me a reason why you don't always have enough to eat?	1. Not enough money for food 2. Too hard to get to the store 3. No working stove available 4. Not able to cook or eat because of health problems	
1b	If enough food, but not the kinds we want, please tell me a reason why you don't always have the kinds of food you want or need?	1. Not enough money for food 2. Too hard to get to the store 3. On a diet 4. Kinds of food we want not available 5. Good quality food not available	
2	In the past 12 months, did you or any of the HH member would run out of food before you get money to buy more, how often did this happen?	1. Often (>6 month) 2. Sometimes (3-5 months) 3. Never true	
3	In the past 12 months, did you or any of your HH member food just did not last, and you did not have money to get more, how often did this happen?	4. Often (>6 month) 5. Sometimes (3-5 months) 1. Never true	

4	In the past 12 months, did you or any of the HH member could not afford to eat balanced meal, how often did this happen?	6. Often (>6 month) 7. Sometimes (3-5 months) 1. Never true	
5	In the past 12 months, did you relied on only a few kinds of low-cost food to feed the children because of shortage of money to buy food, how often did this happen?	8. Often (>6 month) 9. Sometimes (3-5 months) 1. Never true	
6	In the past 12 months, did you feed children unbalanced meal because you couldn't afford the balanced meal, how often did this happen?	10. Often (>6 month) 11. Sometimes (3-5 months) 1. Never true	
7	In the past 12 months, did your children couldn't eat enough food, because you just couldn't afford enough food, how often did this happen?	12. Often (>6 month) 13. Sometimes (3-5 months) 1. Never true	
8	In the last 12 months, did you or other adults in your household ever cut the size of your meals or skip meals because there wasn't enough money for food?	0= No (skip Q9) 1= Yes	
8a	If yes, to Q. 8, how often did this happen?	1. Almost every month 2. Some months but not every month 3. In only one or two months	
9	In the last 12 months, did you ever **eat less than you felt you should** because there wasn't enough money to buy food?	0= No 1= Yes	
10	In the last 12 months, were you ever hungry but didn't eat because you couldn't afford enough food?	0=No 1=Yes	
11	In the last 12 months, did you lose weight because there wasn't enough food?	0= No 1= Yes	
12	In the last 12 months, did you or other adults in your household ever not eat for a whole day because there wasn't enough money for food?	0= No (skip Q13) 1= Yes	
12a	If yes, to Q. 12, How often did this happen?	1. Almost every month 2. Some months but not every month 3. In only one or two months	

13	In the last 12 months, did you ever cut the size of any of the children's meals because there wasn't enough money for food?	0= No 1= Yes	
14	In the last 12 months, did any of the children ever skip meals because there wasn't enough money for food?	0=No (skip Q15) 1= No	
14a	If yes, to Q. 14, How often did this happen?	1. Almost every month 2. Some months but not every month 3. In only one or two months?	
15	In the last 12 months, were the children ever hungry but you just couldn't afford more food?	0= No 1= Yes	
16	In the last 12 months, did any of the children ever not eat for a whole day because there wasn't enough money for food?	0= No 1= Yes	

Thank you for your attention and response!

In case we want to talk to you, please can we have your mobile number? _____

Time the interview time ended: (HH:MM) _____

Questions for key informant and focus group discussion

Objective: To have in-depth discussion on improved potato varieties adoption, and nutrition indicators Complement the household survey data.

1. What crops are grown in the kebele?
2. What are the main crop production challenges? ----
3. When potato production is stated in the kebele? ----------
4. When farmers in the kebele start to produce improved potato? ----------
5. What are the varieties grown in kebele? ----------
6. From where farmers get to produce improved potato planting material? ------
7. Why farmers prefer improved potato varieties? And what are the preference criteria? ----------

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8. What are the main constraints in potato production? ------
9. How potato production constraints can be solved/improved? ----------
10. What is the advantage of producing potato comparing with other crops? ----------
11. What resource/service are most important for potato production? ----------
12. Why all farmers did not adopt potato and what are the factor for low rate and intensity of adoption? ----------
13. What factor contribute for high potato yield? ----------
14. What factor contribute for low potato yield? ----------
15. What are the problems in marketing of Potato? ----------
16. When usually potato is harvested in the kebele? ----------
17. How potato reduce food shortage and hunger? ----------
18. How potato contribute towards ensuring small holder farmers food security? ------
19. Do you think potato can increase the food diversity? How? -----

Thank you for your attention and response!

BIOGRAPHY

Mr. Mohammed Ebrahim was born in South *Wollo Zone* at Kallu woreda in *Amhara* regional state, on September 1980 E.C. He completed his primary and secondary at Degan primary and Combolcha secondary and preparatory school. He joined wolayita Sodo University in 2000 E.C. and awarded his first degree in Rural development and Agricultural Extension in 2002 E.C. Then he joined Ethiopian Agricultural Research Institute (EIAR) in 2003 E.C. as Junior Agricultural extension researcher. Then, he joined International Livestock Research Institute (ILRI) in 2006 E.C as research site coordinator for Africa RISING project and still working there. Then after, Mr. Mohammed was joined Bahir Dar University College of Agriculture and Environmental Science in 2008 to specialize in Agricultural Economics.