Effect of the improved sweet potato varieties on household food security: empirical evidence from Kenya

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Invited paper presented at the 5th International Conference of the African Association of Agricultural Economists, September 23-26, 2016, Addis Ababa, Ethiopia

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Abstract

This study evaluates the effect of improved sweet potato varieties on household food security. Data was collected from cross sectional survey of 164 sweet potato farmers in Kenya. Food security was measured using the Household Dietary diversity Score (HDDS) and endogenous switching probit model used to assess the effect of improved sweet potato varieties on household food security. Off-farm income, output of sweet potato, farm size, land tenure and government extension were the main drivers of food security. Findings were that adopters of improved varieties were likely to be food secure compared to their counterfactual case of not adopting the improved varieties. Additionally, non adopters would do no better or worse than a random individual if they adopt the improved sweet potato varieties. Policies that increase improved sweet potato variety productivity and ease farmers' adoption constraints can ensure that farmers diversify farm income to enhance the food security of households.

Key words: Improved Variety, Food security, endogenous switching probit model, adoption, Kenya

Introduction

The larger Sub-Saharan Africa, agricultural productivity depends on the adoption of agricultural intensification strategies which entails investments in modern inputs and technologies However in these regions agriculture is often characterized by low use of modern technology and low productivity (Kassie *et al*., 2011). These new technologies have been found to enhance food security both by raising production levels and for example, reducing poverty though raising the income of farm households, raising employment, and lowering the price of food (de Janvry and Sadoulet 2001). Agricultural research and technological improvements are therefore crucial to increasing agricultural productivity and thereby reducing food security in order to cub the increasing population.

Sweet potato is among the world's most important, versatile, and underexploited food crops with more than 133 million tons in annual production. Worldwide, sweet potato is the sixth most important food crop after rice, wheat, potatoes, maize, and cassava while in most of the developing nations sweet potato is the fifth most important food crop (CIP, 2013). It is an important food security crop for rural household and has a high yield potential that may be realized within a

relatively short growing season. It is also adaptable to a wide ecological range of 0 to 2000 meters above sea level. In Kenya, over 75% of sweet potato production is concentrated in western, central and coastal areas of the country. Out of this, over 80% is grown in the Lake Victoria basin (Gruneberg *et al*., 2004). In western Kenya, farmers grow landrace varieties that are preferred locally but lack consumption appeal for distant markets.

The area under production grew from 20,181 hectares yielding 527,470 tons (valued at KSh 4 billion) in 2009 to 22,989 hectares in 2011 yielding 1,000,267 tons valued at KSh 7.6 billion (HCDA, 2012). Sweet potato is the third most important food crop in Kenya after maize and Irish potato (CIP, 2013). It is a low-input crop making it ideal for many smallholder households. Its contribution to nutrition security has increasingly been recognized, prompting several entities to support tailor-made interventions specifically targeting the sweet potato value chain. The sweet potato is widely enjoyed, and with increasing awareness of its nutritional value and the steadily growing Kenyan population, demand is expected to increase significantly. This presents increased production potential for domestic consumption and subsequent marketing opportunities that cannot be satisfied by the prevailing production levels. The crop is mainly consumed fresh, with negligible exploitation of processing opportunities due to lack of consumer awareness on utilization of sweet potato in processed form.

Important research efforts have been devoted to select, breed, and disseminate new sweet potato varieties that enhance the productivity and quality of food crops, alleviating poverty and food insecurity. The crop is considered as one of the "orphaned" crops along with cassava, amaranth and millet among others because less research and promotion has been accorded to them compared to crops like maize and rice, but increasingly more such crops are being liberated from their orphaned nature as their qualities of nutrition; low input requirements and drought tolerant are being appreciated in the face of population pressure increase need for food (KACE, 2012). These efforts are a result of the recognition of the important role of these crops in contributing to food security through increasing food supply to both the producers and consumers and generating income to the producers.

In sub-Saharan Africa, where questions are often raised about the adoption and impact of agricultural technology, quantitative evidence of the relationship between agricultural technology and household welfare is scarce (Minten and Barrett, 2008). In more recent studies in Tanzania, Amare *et al*. (2012) found that maize and pigeon pea intensification results in higher per capita income and per capita expenditure on food. However, they used a binary treatment effect approach, which does not account for the heterogeneous effects of adoption. Asfaw *et al*. (2012) in Tanzania found that adoption of improved varieties of pigeon peas significantly increased per capita consumption expenditure and

reduced poverty. Kassie *et al*. (2011) assessed the link between the adoption of improved groundnut varieties and poverty, and found that poverty was significantly reduced when improved varieties of groundnut were adopted. Similarly, Kijima *et al*. (2008) in Western Uganda found that the introduction of a new variety of rice for Africa (NERICA) decreased poverty to a significant extent without worsening income distribution. Alene *et al*. (2009) found that adoption of improved maize varieties in West and Central Africa increased from less than 5% in the 1970s to 60 % in 2005, significantly reducing poverty. Karanja *et al*. (2003) also showed that the adoption of maize technologies in areas of Kenya with high agricultural potential is likely to have a substantially greater positive impact on household incomes than in areas with a low agricultural potential.

International organizations and governments expect improved varieties to alleviate malnutrition and hunger, but, to date; impact assessment studies have mainly focused on productivity and aggregate welfare measures. This study makes the following contributions to the existing literature: firstly fewer studies have documented the impact of technology adoption on household food security (Kabunga *et al*., 2014; Rusike *et al*., 2010 and Shiferaw *et al*., 2014). Various reasons explain the limited number of studies on food security. Nutrition is one of the last outcomes to be affected along the long adoption impact pathway (Chung, 2012). Because of the important lag between adoption and improvement in nutritional status, one might fail to detect impact. Secondly, measuring food security, due to its multidimensionality, is challenging and consensus on the methodology to use is lacking (Barrett, 2010; Coates, 2013).

Materials and methods

Primary data was used for this study. The primary data was collected based on 2014 cropping season using detailed structured questionnaires, with the assistance of an enumerator. The interview methods of data collection were used. The study adopted a cross-sectional sample survey design. The population for the study is dichotomous in nature as such it comprised of adopters of the improved sweet potato varieties and the non adopters in Bungoma County. The list of both adopters and non adopters were obtained from the Ministry of Agriculture, Livestock and Fisheries in the county. This formed the sampling frame for selection of the sample. The study will be conducted in Bungoma County located in Western part of Kenya. The county borders the Republic of Uganda to the West, Teso and Busia counties to the South West, Mumias to the South, and Trans-Nzoia to the North East. The County has an area of 3,032.2 sq. Km and a population density of 453.5 people per sq. Km. It lies between 1,200 and 1,800 meters above sea level and experiences mean temperatures of 23^{o}C. Its latitude stands at 1^{0} 13’ with the longitude of 34^{0}56’North East of the equator in Western Kenya. It also experiences a bimodal type of rainfall with the average annual rainfall ranging from 1200mm to 1800mm per annum. Most of the rain fall is experienced in the months of April-May and July-

August .The target population of the study consisted of sweet potato farmers in Bungoma County. Multi-stage sampling procedure was used to arrive at the surveyed sample of 164 farmers.

Food Security Measurement

FAO and WFP (2009) defines food security as a situation whereby "all people, at all times, have physical, social, and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life". There are four dimensions of food security: (1) availability, (2) access, (3) stability, and (4) utilization of food.

In measuring food security status, this study used the using 7 day recall where Household Dietary Diversity Score (HDDS) was used (Hoddinott and Yohannes, 2002). Dietary diversity is a qualitative measure of food consumptions that reflect household's access to wide variety of foods and it's a proxy of nutrient adequacy of the diet for household. It is meant to reflect, in a snapshot, the economic ability of a household to consume a variety of foods. That is, respondents were asked if they consumed the following food staff in the last twenty-four hours.

A = Cereals; B = Vitamin rich vegetables and tubers; C = Root and tubers; D = Dark green leafy vegetables; E = other vegetables; F = Vitamin A fruits; G = other fruits; H = Meat, poultry, offal; I=Eggs; J = Fish and seafood; K = Pulses/legumes/nuts; L= Milk and milk products; M = Oil/fats; N =Sugar/honey.

Expected responses were yes = 1 or no = 0.

A-M represents the food groups consumed by members of the household. Values for A through M will be either 0 or 1. Long reference periods were deliberately avoided as these could result in less accurate information due to imperfect recall. According to Swindale and Bilinsky (2005) the household dietary diversity score is the

calculated as follows:

HDDS (0-14) = Sum (A + B + C + D + E + F + G + H + I + J + K + L +M+N) (1)

This reflects the total number of food groups consumed by members of the households. A shorter recall period would risk missing foods served habitually but infrequently at the household level or it would overestimate the consumption if the survey is done over those special days. For the subjective food security measure, we follow Mallick and Rafi (2010)'s four category food security assessment made by the household as our outcome variable s, where *1 = Chronic food insecurity, 2 = Transitory food insecurity, 3 = Break-even, and 4 = Food surplus*. However, because some of the categories have few observations relative to others, we also estimate a binary probit model to check robustness of the results. In doing this, we distinguish between different levels of food security by combining

them into two: *food-insecure* (combining Chronic and Transitory food insecurity) and *food-secure* (combining Break-even and Food surplus) as done by…….. Hence, households consuming less than 6 food groups are considered to be food insecure; those consuming 6 to 12 food groups are food secure.

Econometric Analysis

While descriptive statistics provide useful information on the extent of food security and the characteristics of adopters and non-adopters, one cannot draw conclusions on the causal effect of the ISVS on food security. Adoption of the new crop is potentially endogenous. One can try to address such endogeneity by explicitly modeling the simultaneity nature of the equations (Heckman, 1979). However, a pooled data estimation of both adopters and non-adopters assumes that the list of explanatory variables have the same impact on both groups of farmers and implies that adoption has an average effect on the whole sample which may not be necessarily true due to selection problems (Heckman, 1979).

The aim of the study was to provide empirical evidence on the effect of improved sweet potato varieties on household food security. Endogenous switching regression model was used, where both observable and unobservable characteristics are accounted for, thus controlling for a 'hidden bias' which could arise when unobservable variables are not taken into account. Ignoring the endogeneity of adoption of improved sweet potato varieties would result in biased estimated parameters. To address the endogeneity problem, this study used the endogenous switching probit model, which accounts for the correlation in the unobserved characteristics in the decision to adopt the ISVs and food security status, which is the outcome variable. Following Lokshin and Sajaia (2011), we consider a household with two binary outcome equations (whether food secure or not) and the criterion function I_i (binary variable of household adoption of improved sweet potato varieties) that determines the regime faced by the household. The potential values are represented as;

$Ii = 1\ if\ \boldsymbol{\gamma Z i} + \boldsymbol{\mu} > 0$ ---------- *(1a)*

$Ii = 0\ if\ \boldsymbol{\gamma Z i} + \boldsymbol{\mu} \leq 0$ ---------- *(1b)*

Regime 1: $Y^*_{1i} = \beta_1 X_{1i} + \varepsilon_{1i} I_i = 1$ if $(I^*_i > 0)$ ---------- *(2a)*

Regime 2: $Y^*_{0i} = \beta_0 X_{0i} + \varepsilon_{0i} I_i = 0$ *if otherwise* ---------- (*2b)*

Where Y^*_{1i} and Y^*_{0i} are latent variables (household food security status) that defines observed food security status Y_1 and Y_0 (whether the household is food secure or not, respectively), Z is a vector of exogenous variables determining adoption of ISVs, X_i is a vector of exogenous variables determining food security status, γ and β are the vector of parameters estimated while μ_i, ε_{1i} and ε_{0i} are disturbance terms. Equation (1) is a probit specification for ISV adoption. The observed food

security status Y_i is defined as $Y_i=Y_1$ if $I_i=1$ and $Y_i=Y_{0i}$ if $I_i=0$. With the assumption of joint normal distribution of μ_i, ε_{1i}, and ε_{0i} with mean of zero, the correlation matrix written as;

$$\Omega=\begin{pmatrix} 1 & \rho_0 & \rho_1 \\ & 1 & \rho_{10} \\ & & 1 \end{pmatrix} \text{-} \quad \text{---------- (3)}$$

Where ρ_0 is the correlation between ε_0 and μ, ρ_1 is the correlation between ε_1 and μ while ρ_{10} is the correlation between ε_0 and ε_1. Consequently, the log likelihood function for the model is given by;

$$\begin{aligned} Ln(\xi) = & \sum_{ci\neq 0, Yi\neq 0, \omega_i} \ln\{\phi_2(X_{1i}, \beta_1, Z_i\alpha, \rho_1)\} \\ & + \sum_{ci\neq 0, Yi\neq 0, \omega_i} \ln\{\phi_2(-X_{1i}, \beta_1, Z_i\alpha, \rho_1)\} \\ & + \sum_{ci=0, Yi\neq 0, \omega_i} \ln\{\phi_2(-X_{1i}, \beta_1, Z_i\alpha, \rho_1)\} \\ & + \sum_{ci=0, Yi=0, \omega_i} \ln\{\phi_2(-X_{1i}, \beta_1, -Z_i\alpha, \rho_1)\} \text{-} \end{aligned} \quad \text{---------- (4)}$$

Where ω_i is an optional weight for the i^{th} household and ϕ_2 is cumulative function of bivariate normal distribution (Lokshin and Sajaia, 2011). Previous studies have used the switching probit regression model in social research (Ayuya *et al*., 2015; Floro and Swan, 2013; Gregory and Coleman-Jensen, 2013; Lokshin and Glinskaya, 2009).The advantage of endogenous switching probit model specification in Eqtn (4) is the possibility of deriving probabilities in counterfactuals cases for household's food security status on adoption of ISVs. Following Aakvik, Heckman, and Vytlacil (2000) and Lokshin and Sajaia (2011) two cases are defined as;

$$\begin{aligned} TT(x) &= \Pr(Y_1 = 1 | I = 1, X = x) - \Pr(Y_0 = 1 | I = 1, X = x) \\ &= \frac{\phi_2(X_1\beta_1, Z\alpha, \rho_1) - \phi_2(X_0\beta_0, Z\alpha, \rho_0}{F(Z\alpha)} \end{aligned} \quad \text{---------- (5a)}$$

$$\begin{aligned} TU(x) &= \Pr(Y_1 = 1 | I = 0, X = x) - \Pr(Y_0 = 1 | I = 0, X = x) \\ &= \frac{\phi_2(X_1\beta_1 - Z\alpha, -\rho_1) - \phi_2(X_0\beta_0 - Z\alpha, -\rho_0}{F(-Z\alpha)} \end{aligned} \quad \text{---------- (5b)}$$

Where F is the cumulative function of the univariate normal distribution, Equation (5a) computes the effects of treatment on the treated (TT), which is the difference between the predicted probability of being food secure for adopters of ISVs and the probability of being food insecure had they not adopted the ISVs. Computing the average of TT(x) on households that have adopted the ISV, results in the average treatment effect on the treated (ATT). The effect of the treatment on the untreated

(TU) was computed by Equation (5b), which is the expected effect on food security status if the non adopters' households had adopted the ISV. Computing the average of TU(x) of households that did not adopt the ISVs results in average treatment effect on the untreated (ATU) (Aakvik *et al*., 2000; Lokshin and Sajaia, 2011).

Variables used in the switching probit model are presented in Table 1.Theoretically, endogenous switching probit model is identified by a functional form (Gregory & Coleman-Jensen, 2013; Lokshin & Sajaia, 2011). The study used exclusion restriction methodology to improve on identification. The study used gender head, sweet potato unit price, farmer to farmer extension and non-governmental extension as instruments. This study however is consistent and exclusive to studies such as Ayuya *et al.*, 2015, Di Falcao *et al*., (2011), Asfaw *et al*., (2012) and also Negash and Swinen (2013) who used agricultural extension sources as instruments in their studies. However, sweet potato and gender head are exclusive for this study. Table 11 presents tests that indicated the above variables as valid instruments. Sargan's test showed the correlation between the instruments excluded and error terms. Sargan test was $Pr>\chi^2$ (1) = 0.5745 and $Pr>\chi^2$ (1) = 0.4520 showing that the excluded instruments were uncorrelated with the error terms. Wald test was used to test the joint significance of the instruments excluded helping in testing the hypothesis of weak instruments. Wald χ^2 test statistics (53.94) for the farmer type indicates a joint significance of the instruments excluded helping in testing the hypothesis of weak instruments. Hence, we fail to reject the hypothesis of weak instruments.

Results and discussion

Descriptive Statistics

The mean for the variables used in the econometric analysis is presented in Table 3. In terms of food security status, 78% and 58% of adopters and non adopters respectively were categorized as food secure. In general, farmers who adopted the ISV had younger household heads participating in off-farm activities and relatively smaller household size. They also sold their outputs at a higher price compared to their counterparts the non adopters. This signifies the quality and value of the ISVs in the market compared to the local varieties. However there was no statistical significant difference on the gender of the household among the two groups. About 58% of the adopters accessed extension services from the Nongovernmental organizations compared to 18% in non adopting households. Non adopters had relatively high group heterogeneity index.

Table 1: Definition of Variables used in the Endogenous switching pr obit Model

Variables	Description of the variables

Food security status	(Food insecure =0, Food secure =1
Off farm income	Off-farm income
Farm size	Farm size in acres
Household size	Household size (numbers)
Wealth	Value of agricultural assets Kshs
Credit access	Dummy = Had access to credit, 0 otherwise
Sweet potato price	Price paid for sweet potato(Kshs)
Land tenure	Dummy = With title deed, 0 otherwise
Number of livestock	Number of livestock owned
Output	Output from last season(kg)
Group heterogeneity	Group heterogeneity index
Gender head	Household head gender (Female=0, Male=1)
Education head	Education of household head (categorical)
Cultural belief	Dummy = affected by cultural factors, 0 otherwise
Training contact	Number of training contact with farmer
Farmer to Farmer extension	Dummy = 1 if the household head got information from fellow farmers, 0 otherwise
Non-governmental extension	Dummy = 1 if the household head got information from nongovernmental organization extension workers, 0 otherwise
Government extension	Dummy = 1 if the household head got information from government extension workers, 0 otherwise

Education measured in terms of 1 = not gone to school; 2 = primary; 3 = secondary; 4 = tertiary; 5 = university.
Marital status measured in terms of 1 = single; 2 = married; 3 = widowed; 4=separated.
The heterogeneity index derived from questions of whether members were from the same neighborhood, occupation, relative, friends.

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Table 2: Mean of the Variables used in the Endogenous Switching Probit model

	Adopters		Non Adopters		
Variables	Mean	Std. Err.	Mean	Std. Err.	t value
Food security status	0.78	0.04	0.59	0.06	-2.7250***
Off-farm income	3.79	0.06	3.52	0.05	-3.0680***
Farm size	0.43	0.38	0.21	0.13	-4.7910***
Agricultural assets	4.53	0.06	4.14	0.05	-4.6640***
Credit access	0.52	0.05	0.26	0.05	-3.4379***
Output price	37.88	2.11	18.07	1.33	-7.3882***
Land tenure	1.96	0.11	2.47	0.12	3.2370***
Output	5086.88	472.56	1668.73	133.17	-6.1746***
Group heterogeneity	3.6	0.13	3.97	0.16	1.8725*
Gender head	0.39	0.05	0.49	0.06	1.3550
Education level	2.73	0.1	2.21	0.1	-3.4502***
Number of livestock	2.01	0.06	2.24	0.07	2.5632**
NGO extension	0.58	0.05	0.18	0.05	-5.5667***

Farm to Farm Ext	0.11	0.03	0.38	0.06	4.3489***
Govt Extension	0.29	0.05	0.41	0.06	1.5831

b) Determinants of farmers' adoption of improved sweet potato varieties

Table 3: Determinants of adoption of improved sweet potato varieties *(first stage)*

Variables	**Coef.**	**Std. Err.**
Household size	-0.1461**	0.0656
Education level	0.0746	0.1656
Off-farm income	-0.1114	0.3092
Farm size	-0.7526***	0.2731
Sweet potato Output	0.0003***	0.0001
Land Ownership	-0.0827	0.1333
Number of livestock	0.0212	0.0361
Sweet potato price	0.0182*	0.0095
Credit access	-0.5503*	0.3160
Value of agricultural assets	0.1968	0.2972
Training contact	-0.1878*	0.1001
Government extension	0.0521	0.7900
Farmer to farmer extension	-0.8349	0.7973
Non-governmental extension	0.5510	0.8156
Cultural factors	-0.1383	0.2761
_Cons	0.1662	1.5657

*, **, ***: significant at 10%, 5% and 1% level respectively

The household size was significant at 5% with negative coefficient which indicates that there is a negative relationship between household size and adoption of improved sweet potato technology. The larger the household size the lower the level of adoption of improved sweet potato varieties. This could be explained by the fact that the average agricultural land available per household is about 0.33 ha (Jaetzold *et al.,* 2006). However this was interesting and inconsistent with many past studies since sweet potato is far much labour intensive. This is concluded by the fact that a small household size is not pressured by the need of to produce more food for a large family size consumption, hence it open and willing to try out new technologies than a larger household size.

Output of sweet potato was found to be a very important factor that influenced the adoption of improved sweet potato varieties among farmers in the study area. The yield variable was found to be positive and significant at 1% level of significance. Yield is a direct measure of seeds performance, and a crop variety that is high yielding stands to be adopted by farmers since high yield would raise output and subsequent gross earning. This finding agrees with that of Ojiako *et al*. (2007) that yield of soybean was significant in influencing the adoption of improved soybean in northern Nigeria.

Adesina and Zinna (1993) also reported that yield significantly influenced farmer's decision to adopt improved mangrove swamp varieties of rice in Sierra Leone.

There is also that tendency that farmers will adopt new innovations because majority of them had access to credit which would enable them to purchase inputs and pay for labornb required in the adoption of new varieties. Credit access enables the farmers get resources that they could invest in marketing activities such as value addition to improve incomes and transportation to better markets with better prices. The CREADIS program model also incorporates a microfinance project whereby farmers can access loans to meet their daily needs. This could act as an incentive given the fact that rural farmers have limited access to finance. Availability of loan upon participation in the program therefore leads to increased probability of adoption.

As expected sweet potato price had a positive significant influence on the adoption of the improved varieties. This implies that a one shilling increase in the price of improved varieties increased adoption by 0.2%. The high quality and favorability in the market translates to its high price over that of the local variety. This is however common with farmers in that with the existence of a new profitable technology, farmers would want to adopt the new technology so as to cover up their cost of production and yield enough profit in the market

Training contacts negatively and significant influenced the adoption of the improved varieties. This result is inconsistent with results of earlier studies (Baidu- Forson, 1999; Faturoti *et al*. (2006) and Mazvimavi and Twomlow, 2009). The negative effect of training contacts implies that most of the training done was general to all farmers and may be customizing the trainings to individual needs of each farmer would better improve its adoption. The more the contacts the farmer has with officers tend to reduce potential intensity of adoption. However, intensive discussions with farmers on the kind of training topics they receive revealed that agricultural training services are more focused on intensifying crop and livestock production and also value addition at the expense of adopting new technologies and techniques.

c) Determinants of food security status

The determinants of food security status are discussed in table 4. The independent variables were selected from past studies on determinants of food security status (Ayuya *et al*., 2015; Kassie *et al*., 2013; Shiferaw *et al*., 2014; Christian and Coleman, 2013). The ρ_0 and ρ_1 (measures of food security status) have opposite signs implying that differences in observed resource endowments and unobservable household characteristics are both important in explaining the difference in food security between the groups. The correlation coefficient of the adopter outcome equation is positive

and significant. Suggesting that individuals who choose to adopt the ISVs would be more food secure than a random individual from a sample would have had they not adopted the ISVs.

Participation of the household head in off-farm income-generating activities increase the likelihood of household being food secure in all the two household type. Results show the vital role of off-farm activities in enhancing household income diversification. These could be explained by the uncertainties and risks facing agriculture in most developing countries. Additionally, participation in off-farm activities increases the access of the decision maker to more information on how to build their household human development indicators. Similar findings were reported by Krishna and Shariff (2011), where participation in off-farm reduced the likelihood of a household being multidimensional poor and increased the probability of escaping poverty in India respectively.

Table 4: Determinants of food security status *(second stage)*

	Adopter		**Non Adopter**	
Variable	**Coef.**	**Std. Error.**	**Coef.**	**Std. Error.**
Marital status	0.2941	0.4300	0.4191	0.3222
Household size	0.0676	0.1361	-0.0617	0.0869
Off-farm income	1.4673**	0.7458	0.9798*	0.5303
Farm size	-1.7234**	0.8621	0.1405	0.2227
Output of sweet potato	0.0009***	0.0004	0.0003	0.0002
Land tenure	-0.5533*	0.3025	0.1431	0.2068
Number of livestock	0.0329	0.1035	0.0540	0.0528
Training contact	0.2304	0.1812	-0.0779	0.1213
Government extension	0.1413*	0.6473	0.7694	0.3980
Cultural belief	-0.1210	0.5069	0.3062	0.4276
Sweet potato buyers type	-0.4944***	0.1502	-0.2035**	0.0885
Constant	-3.9313	2.9448	-4.6600	2.1551
ρ_0			-0.4710	0.8893
ρ_1	0.9842**	0.8674		
Lr. Test for independent. Eqns. (rho 1= rho0) *chi2* (2) = 2.90 prob>*chi2*=0.0054***				

Note: *, **, ***= significant at 10%, 5% and 1% respectively

Land tenure had a negative and significant effect on food security at 10% level. This result justifies significant association of land tenure of sweet potato farmers. A high number of farmers without title deed on both the adopters and non adopters with 38% and 42% are not able to undertake risk or entrepreneurial ventures such as adopting of new technologies. These farmers have to be sure on the

good performance of the technologies before adopting them since many of them have no secure rights on their land.

The output of sweet potatoes realized by a household, not surprisingly, had a positive impact on food security for adopter household. High output positively increased the likelihood of an adopter household being food secure. An increase in production leads to a substantial increase in food surplus and hence the surplus could be sold to earn extra income. These households can therefore buy other food groups and diversify their diet.

Surprisingly Sweet potato buyer type had a negative effect on food security (in favor of middlemen) in both the households but significantly on the adopter household. Hence where there was existence of middlemen the adopters sold their output to them. Middlemen are known to exploit the farmers by offering lower prices compared to the market prices and in turn farmers end up not breaking even in their enterprises. On the other hand, selling of the sweet potato on the market also attract dismal prices since it will be competing with the other local varieties. These affect food security in the sense that the farmers will be discouraged to produce for commercial purpose and just produce for subsistence. There would be low or no surplus produce for sell to get extra income to buy food. Hence consumers and farmers would no physical, social and economic access to sufficient food which meets their dietary needs.

Consistent with a study by Shiferaw *et al*., (2014) on Adoption of improved wheat varieties and impacts on household food security in Ethiopia, government extension contact positively and significantly at 5% increased the likelihood of the adopter household being food secure. Farmers who came to know improved varieties via extension agents are more likely to be more food secure compared to those who were informed by other dissemination pathways, probably because the predominant public extension system provides more reliable information on improved varieties and associated agronomic practices. However, constant visits by CREADIS extension officers on the adopters in the county led to farmers' willingness to learn a lot of the topics including value addition, Marketing and production techniques.

Cultural belief although not significant, its coefficient shows it could affect food security status negatively. This is a great concern in the study area; since farmers have negative belief in new technologies especially the improved varieties therefore they tend to stick on the local varieties.

d) Mean treatment effects

The effect of adoption of improved sweet potato varieties on food security is shown in Table 5, which was estimated by equation and as detailed by Lokshin and Sajaia (2011). The values across the diagonals (in cell (a) and (d)) represent the mean values of participants and non- participants in

the sample. The values in cell (b) and (c) are the counterfactual expected values. The average treatment effect on the treated (ATT) was 0.0778, which is the actual effect that adopters experience through adoption. This implies that among the adopters, their adoption of improved sweet potato varieties led to a higher probability or more likelihood of being more food secure compared to the counterfactual case of not adopting the ISVs. Hence, adoption of the ISVs substantially improved the food security of the adopter households.

Table 5: Mean Treatment effects on Food Security

Treatment effect	Decision stage			
	Adopter		Non adopter	
	Estimate	Std Error	Estimates	Std Error
Average treatment effect on the treated (ATT)	(a) 0.7835	(0.0330)	(c) 0.7057	0.0309
Average treatment effect on the untreated(ATU)	(b) 0.5207	(0.0489)	(d) 0.5885	0.0323
Heterogeneity effects	0.2627***		0.1171**	

Notes: ****, ***** imply significance at 5% and 1% respectively. The standard errors are in parentheses

Conclusion and policy recommendations

The study aimed to characterize sweet potato farmers, determine factors influencing adoption and the extent of adoption of the ISVs and lastly to assess the contribution of the ISVs on household food security in Bungoma county, Kenya. Majority (57%) of the sweet potato farmers had adopted improved varieties while only 43% were still planting the local varieties. This mainly is because of the location of the KALRO which together with CREADIS which is a non-governmental organization was contracted by KALRO to distribute, contract and educate sweet potato farmers on the new improved varieties in the area. We find that adopting the improved sweet potato varieties increased households' food security significantly. The effects are substantial. Our findings indicate improvements in increased food diet diversity and household overall income. Adoption of the improved varieties reduces liquidity constraints as they can be harvested at periods of food shortages and can contribute to mitigate seasonal gaps in food availability. In addition, adoption of the variety improves access to other food groups and farm inputs for these households, which improves overall crop productivity. Our analysis also suggests that adoption of the ISVs is heterogeneous across households. We find rational sorting based on comparative advantage from the technology/crop where adopters gain significantly from adopting which they may not otherwise. Households, who do not adopt, appear to do this because they would not benefit. This is in line with findings of other studies. We have found that non-participating households have made a rational choice not to participate in that they are better off without adopting the sweet potato improved varieties.

Participation in off-farm income activities by the household head, high output, government extension, land tenure and sweet potato buyer type were important drivers in determining food security status. Participating in off-farm income activities increased the probability of being food secure in both the household types. This raises a policy concern on the importance of diversifying farm income through creation of sustainable off-farm activities. Of concern also is the effect of government extension which significantly increased the probability of being food secure. Farmers should be sensitized on socio-cultural aspects that hinder adoption of technologies in the county. This calls for the need to strengthen extension services by the government since farmers get most of their information about new technologies from them. Further, the choice of the sweet potato buyers should be cautious by the farmers since it negatively reduced the probability of the adopters being food secure. For public policy, these findings underpin the importance to strengthen contractual agreements in marketing to wipe out middlemen in the process and assure farmers constant market for their produce.

References

APPENDIX

	First stage		**Second Stage**	
	Farmer type		**Food status**	
Variable	**Coef**	**Std. Error**	**Coef**	**Std. Error**
Gender head	-0.3402	0.3416	-0.5568*	0.3297
Sweet price	0.0693***	0.0194	0.0129	0.0135
Farmer to farmer Extension	-0.4803	0.9921	-1.7451	1.0075
Non-governmental Extension	1.3843	1.0303	-1.9017*	1.1145
Constant	-1.3285	2.3308	-5.9924*	1.9204
Wald test	128.92		90.40**	

Note: *, **, ***= significant at 10%, 5% and 1% respectively.