The Impact of Agriculture Technology Adoption on Farmers' Welfare in Uganda and Tanzania

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Abstract

The paper looks at the determinants of technology adoption and how this affects farmers' welfare measured by consumption expenditure in Uganda and Tanzania. The study uses panel datasets based on the Living Standards Measurement Study-Integrated Surveys on Agriculture for the period 2005 to 2015. To do this, we use both a probit and linear probability model for the determinants of improved new seeds varieties. In addition, the impact of technology of welfare is based on endogenous switching regression. This helps us to control for selection problems on production and adoption decisions. The determinants of both countries include farm size, contact with government agencies, number of improved seed varieties and credit. However, there are determinants that are specific for each country. The results for the impact of improved new seeds varieties on welfare, show that households that use improved new seed varieties tend to be different from those that do not. They also have higher consumption expenditure. The results show the potential of improved seeds varieties in helping households in especially in rural areas increasing their welfare.

Keywords: Household welfare, Technology adoption, Sub-Saharan Africa, Uganda, Tanzania, Endogenous switching

Introduction

Since the late 1970s to mid-1980s, many African countries implemented macroeconomic, sectoral and institution reforms aimed at ensuring high and sustainable economic growth, food security and poverty reduction. Despite all these accelerations, the agricultural sector's growth has remained insufficient to adequately address poverty, attain food security, and lead to sustained GDP growth on the continent (Dessy *et al.*, 2006). More worrying is that the sector remains characterized by low use of modern technology and low productivity and thus unable to meet the increasing food needs of a growing population. While there has been some evidence of new crop varieties in some countries in Africa, adoption rates remain far below countries in Asia, casting doubts on the possibility of a green revolution. For example, in 2000, African adoption rates of modern varieties of rice, wheat and maize per area harvested were less than half those of rates in East and Southeast Asia, and the situation has not changed much (Dethier & Effenberger, 2012). Hence, research and adoption of technological improvements are crucial to increasing agricultural productivity and reducing poverty, while sustaining the agro-ecosystems that support livelihoods (Kassie *et al.*, 2011; Asfaw *et al.*, 2012).

This study seeks to examine the constraints behind the low adoption of agricultural technology[1] in East Africa as well as the impact of adoption on household welfare. The agricultural sector is arguably the most important engine for realizing East Africa's economic growth and development, job creation and poverty reduction (Odame et al., 2013). Generally, the sector accounts for 43% of the Gross Domestic Product (GDP) and 60% of exports in the East African states (EAC, 2015). Nearly 70% of the population and about 90% of the poor in the region rely heavily on agricultural production to liberate them from poverty. Therefore, the growth of agricultural productivity in East Africa is very critical for economic development and livelihoods of many people. Like the rest of Sub-Saharan Africa, this region has low adoption rates of agricultural technology and small holder farmers remain poor and largely concentrated within the rural areas. To understand low adoption rates of new technologies, one needs to keep in mind the factors that determine a farmer`s adoption behaviour. While low adoption rates might seem irrational when looking at promised yields, they may well be a result of rational decision making by farmers given the various constraints they face. Technology adoption in general has been found to be positively related to a farmer`s schooling and wealth, and the adoption of the same technology by neighbours. Although this does not establish causality, it suggests that low education, missing credit markets and externalities could be major barriers to technology adoption (Foster & Rosenzweig, 2012).

Several theoretical frameworks have been suggested on farmers' decisions to use improved technology (Feder & Slade, 1984; Abadi & Pannell, 1999; Negatu & Parikh, 1999; Isham, 2002). A model of technology diffusion based on human capital propounded by Feder & Slade (1984) argue that farmers with huge tracks of land and more education have more knowledge of improved agricultural technology and are therefore more likely to incorporate technology in their farming faster. This argument was extended by Isham (2002) who included social capital as fixed input into the decision to adopt improved technology. His model postulates that farmers with more labour force, and those with neighbours who employ improved technology, amass more information and embrace new technology faster. According to Negatu & Parikh (1999), technology is transferred from sources such as extension agents and the media to the farmer depending on the farmer's characteristics, farmers factor endowments and determined by the prevailing agro-ecological, socio-economic and institutional factors.

These models have been extensively tested using data from both developing and developed countries, investigating especially factors behind use of chemical fertilizers and improved seed varieties (Green & Ng'ong'ola, 1993; Zeller et al., 1998; Negatu & Parikh,1999; Isham, 2002). These studies identified the size of the farm, family labour force, land tenure, access to finance and products markets, information access, participation in off-farm activities, social capital, household characteristics, ecological and environmental factors to play a crucial role in decision making on new technology adoption. Other studies have also established several factors ranging from physical, socioeconomic, as well as mental that play a crucial role towards the adoption of technology (Feder et al., 1985; Neupane et al. 2002; Rogers, 2003). It

[1] Agricultural technology adoption is the application of mechanical technology and increased power to agriculture (Moyo et al. 2007). It involves use of tractors, human-powered and animal-powered implements, irrigation systems, food processing and related technologies, new seed varieties and equipment.

has also been found that the probability of young farmers to adopt improved technology is higher because they are considered to be more enlightened and hence susceptible to attitude change than the old generation (CIMMYT,1993).

Empirical studies argue that adoption of agricultural technologies can reduce poverty both directly and indirectly (Becerril & Abdulahi,2010; Moyo et al. 2007). The direct effects include the productivity gains and low cost of production which can improve income of the adopters while the indirect benefits from the technology adoption may come in the form of increased supply which may lower food prices. The increased productivity may also stimulate demand for labour which may translate into increased employment and earnings for the poor who usually supply labour to the farms. Adoption of improved technology has been identified as a key measure towards achieving food security (Langyintuo et al., 2008). Peasant farmers have the potential to enhance their welfare as well as their food security situation if they make use of improved agricultural technologies (Mendola, 2007).

Within East Africa, several studies have examined the constraints behind technology adoption as well as its impact on household welfare. The most recent studies have largely focused on evaluating the impact of technology adoption on household welfare in Tanzania. In this category, Asfaw *et al.* (2012) examined the impact of adoption of improved pigeon pea technologies on consumption expenditure and poverty status using cross-sectional data of 613 households in Tanzania. They found that adoption of pigeon peas significantly increased consumption and reduces poverty. Similar results were obtained by Amare *et al.* (2012) using the same dataset. In addition, they also found that determinants of technology adoption included inadequate local supply of seeds, access to information, human capital and access to private productive assets as key constraints for pigeon peas technology adoption. In a related study, Asfaw *et al.* (2012) also examined the impact of adoption of improved legumes technologies on rural households' welfare measured by consumption expenditure in Tanzania and Ethiopia. Using the same data for Tanzania and a sample of 700 households in Ethiopia, they found similar results.

In Uganda, Kassie *et al.* (2011) evaluated the ex- post impact of adoption groundnuts varieties on crop income and poverty. Their study utilized cross-sectional data of 927 households, collected in 2006 in seven districts. The positive and significant impact on crop income is consistent with the perceived role of new agricultural technologies in reducing rural poverty through increased farm household income. Kiiza *et al.* (2012) has also shown that access to market information has a positive and significant impact on the intensity of adopting improved seed for all crops while adoption of improved seed has a positive and significant effect on farm yields and gross farm returns. Suri (2011) using data from Kenya, investigated the empirical puzzle: the low adoption rates of like hybrid maize that increase average farm profits dramatically. The study found that benefits and costs of technologies are heterogeneous, so that farmers with low net returns do not adopt the technology.

Based on literature analysis, there is evidence of increased work on the adoption of agricultural technology and how this affects households. However, these studies are largely cross sectional in nature, based on similar datasets and focusing on very limited aspects of agricultural technology. While, most studies within this literature are based on cross-sectional analysis casting doubts to the reliability of the results[2]. While most studies have focused on

[2] Such an approach may suffer from inefficient parameter estimates, leading to inaccurate inferences of model parameters, since it disregards cross-period correlations. In addition, it is difficult to control the impact of omitted variables, leading to biased or unreliable estimates. Moreover, contemporaneous correlation across the

the impact of adoption of technology on household welfare, the constraints to adoption of this technology have not received adequate attention. Hence, assessing the constraints behind the low adoption of agricultural technology in East Africa as well as the impact of adoption on household welfare, can assist with setting priorities, providing feedback to research programs, guiding policy makers and those involved in technology transfer to have a better understanding of the way new technologies are embraced and diffused into farming communities. The study will is based on panel analysis, using a new database from the World Bank's, Living Standard Measurement Survey-Integrated Surveys on Agriculture (LSMS-ISA). Panel data is available for both Uganda and Tanzania. By using this approach, the study hopes to provide fresh insights into the constraints hindering agricultural technology adoption as well as the impact on household welfare.

As shown in Asfaw et al. (2012), analysing the impact of adoption of technology on farmers welfare is challenging because of unobserved heterogeneity and possible endogeneity. First, there could be bi-causality between technology adoption and farmers welfare. Technology adoption can result in increase agriculture productivity and better welfare. However, better welfare for the farmers can result in increased adoption of technology. In terms of uobservserved heterogeity, it's possible that farmers that adopt technology could be different compared those that do not in terms of welfare outcomes. To address this issue, we use of endogenous switching regression method, we estimate the parameters simultaneously using the Full Information Maximum Likelihood (FIML) method.

The rest of the paper is organized as follows. Section two provides an overview of technology adoption and farmers welfare in Uganda and Tanzania. The third section presents the conceptual framework and analytical methods with emphasis on empirical models and hypothesized relationships. Datasets, sampling and survey design and descriptive results are presented in section four. The main analytical results are presented and discussed in section five. Section six concludes by presenting the key findings and the policy implications.

Overview of Agriculture Technology Adoption and Welfare in East Africa

East African countries can be characterized as "agriculture-based," that is, agriculture is the backbone of these economies. In addition, agriculture is dominated by smallholder farmers. Moreover agriculture in East Africa accounts for about 75% of the labour focus and is an important sector in job creation and poverty reduction across countries. Smallholder farmers account for about 75% of agriculture outputs with farm sizes of about 2.5 Ha on average producing mainly for home-consumption, and using traditional technologies. Besides, less than 4% of total land area is irrigated. Major crops include cereals, root crops, banana tea, pyrethrum, sisal, cut flowers, coffee, cotton and tobacco. Coffee, cotton, horticulture produce and tea are the main export crops. Cattle and poultry dominated the livestock sub-sector. Other important livestock produced are sheep, pigs and goat. Forestry, horticulture and fishing are also important economic activities in most of the study countries. In these countries, food security remains a challenge, despite the significant boost in agricultural productivity. They also have low productivity in agriculture (Salami *et al.*, 2010).

The impact of agricultural productivity has attracted the attention of policy makers and development partners in the East Africa region for two main reasons. The first reason is that

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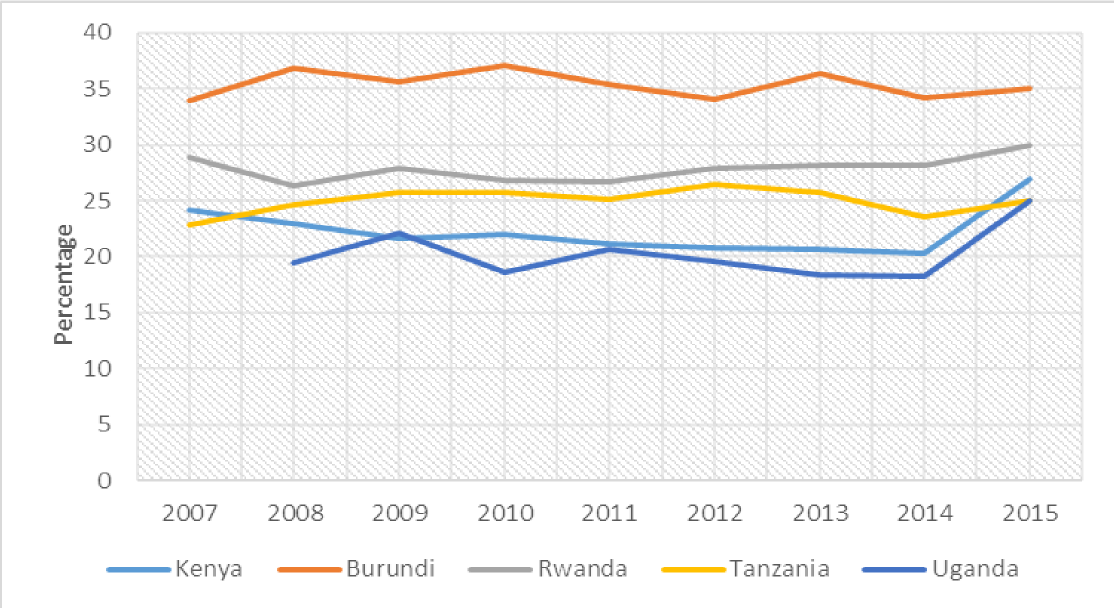
cross-section does not imply causation, and thus these models may suffer from endogeneity biases. Furthermore, these problems are difficult to address satisfactorily since suitable instruments are often not available.

the region relies heavily on this sector for economic growth and development. For example, agricultural sector accounts for the biggest share of the East African Country's Gross Domestic Product (GDP) relative to other sectors of the economy (see figure 1). Secondly, there is evidence that agricultural productivity is gradually declining in East Africa as well as in other sub-Saharan countries. The declining trend in both land and labour productivity is a major challenge and an indication of declining living standards for farmers and the rest of the economies. Growth in agricultural productivity is a strong predictor of poverty reduction because of its vital relationship with wages, household self-employment and the real incomes of the poor (Zendilo, 2015).

Figure 1: Contribution of Agricultural Sector to GDP



Source: Computed from East African Community Facts & Figures (2015)

Since time immemorial, the Consultative Group on International Agricultural Research (CGIAR) and its member centers have led studies concerning the adoption of new technologies in agricultural production by farmers in emerging economies (Doss, 2003). These scientific and technological improvements have greatly benefited farmers in the developed countries by enhancing agricultural productivity. Advanced agricultural technologies such as improved seeds, modern irrigation practices, soil and water conservation, application of fertilizers just to mention but a few, are widely seen as key avenues for fixing low agricultural productivity in the region. Like other developing world, governments of East Africa have over the years adopted the idea of green revolution as a strategy to enhance production, reduce poverty and realize food security (Mugisha & Diiro, 2010). One of the key pillars of the EAC's comprehensive development frameworks for modernizing agriculture so as to counter factors responsible for low productivity is research and development.

With aid from development partners, governments of EAC have established several efficiency and productivity-augmenting technologies, projects as well as programmes at a household level (Ogada et al., 2014). In Kenya for example, the notable programmes and projects established include: The National Accelerated Agricultural Inputs Access Programme (NAAIAP), the Kenya Agricultural and Productivity Project (KAPP), the

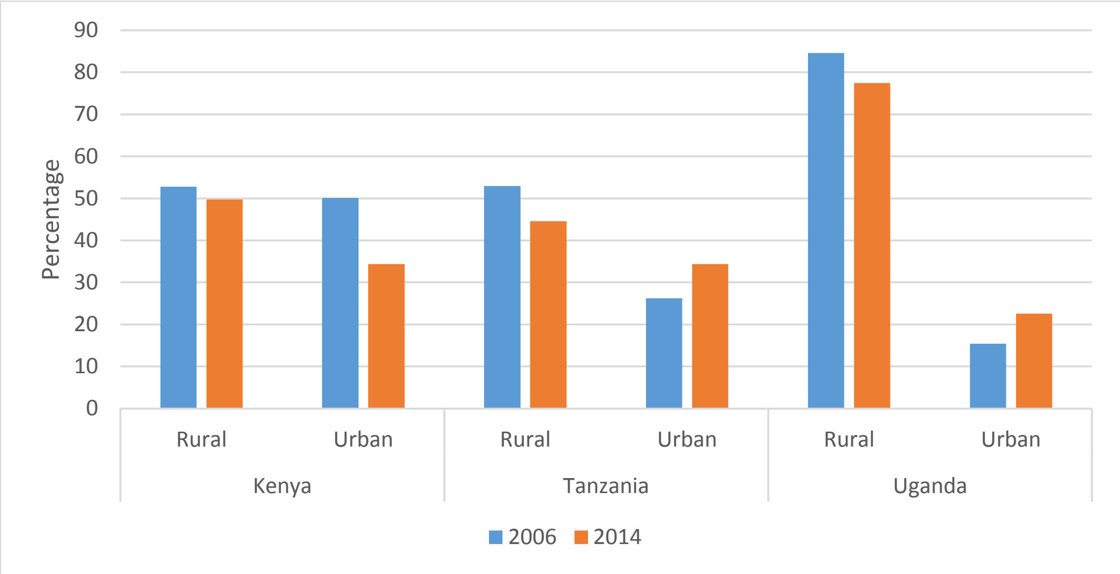
National Agricultural and Livestock Extension Programme (NALEP) and the Agricultural Sector Programme Support (ASPS). In addition, Kenya Agricultural Research Institute have developed and disseminated improved technologies for water and soil conservation, improved seeds, improved storage facilities and labor-saving technologies. Tanzanian government launched a National Agriculture Input Voucher Scheme to give farmers 50% subsidy on fertilizers and improved maize seeds in 2009. This was complemented by the immense support given by the government to agricultural research institutions and extension services to develop and disseminate improved technologies to farmers so as to enhance their welfare through improved crop and livestock production (Lyimo, 2014). These developments were mainly focused on adoption of current agricultural technologies such as improved seed varieties, use of agro-chemicals, reduction of production costs, transition from subsistence to commercial farming, increase income of the technology adopters and afterward improve the wellbeing of the farmer (Kassie et al, 2011 & Mendola, 2007 in: Mukasa, 2015).

The establishment of the National Agricultural Advisory Services (NAADS) in 2001 for the case of Uganda was a major boost to the agricultural sector. This program was a replacement of the agricultural reforms dating back in early 1990s which aimed at promoting cash crops (coffee, cotton, tea, and tobacco) for exports. NAADS focuses on disseminating agricultural technology and extension services to the farmers with the main objective of changing orientation of farmers from subsistence to commercial agriculture (Bahiigwa et al., 2005). NAADS system is demand-driven operating through farmer's organizations, and not through producer cooperatives as the earlier program.

Generally, Governments of EAC and their development partners have invested a lot of resources towards the development of agriculture productivity-enhancing technologies. Key among them being improved crop varieties, agronomic practices, disease and pest control techniques as well as natural resource management (NRM) techniques. The new crop varieties are more than 800 and improved livestock breeding methods like artificial insemination, transfer of embryo technology, and feed formulation are also available (World Bank, 2008). Despite all these developments, there is low level of adoption of these technologies in Sub-Saharan Africa (World Bank, 2008; Odame et al., 2013). An evaluation by ASARECA (Association for Strengthening Agricultural Research in Eastern and Central Africa) show that adoption of dairy technologies in East Africa is less than 20%, while that of hybrid maize is 40-70% in Kenya and Tanzania (Odame et al., 2013). The same study reveals that Kenya is the leading in dairy productivity followed by Sudan as results of higher rates of technology adoption. Statistics show that 50% of farmers who had earlier adopted NERICA (improved rice), abandoned it within two years of cultivation (Kijima et al., 2011), despite of the evidence that adoption of improved technology agricultural practices attract high returns in Uganda. A study by World Bank (2006) in Uganda revealed that adoption of improved seeds was associated with a 21% increase in crop production for Ugandan farmers. There is little demand of improved maize seeds by farmers despite decades of agricultural policies which promoted the adoption of improved variety of seeds that are highly productive and resistant to diseases as well as drought. This problem has been attributed partly to lack of farmer's awareness of such technology, availability and marketability of the improved seeds which is also very low (ASARECA, 2012; RLDC, 2009).

Agriculture is predominantly a rural phenomenon where majority of the population practice small scale farming. According to FAO (2009) estimates, there were 265 million undernourished people in Sub-Saran Africa, 98 million more than in 1990/1992. Poverty is still prevalent in rural East Africa relative to urban areas, despite the many years of development, dissemination and implementation of various technologies to enhance agricultural productivity through (see Figure 2). For example, in 2014, the proportion of rural poor was 49.7% and 34.4% in urban Kenya, while during the same year the proportion of the poor population in Tanzania stood at 44.6% for rural and 35.4 for urban. In Uganda, 84.6% of the poor live in rural areas while 15.4% reside in urban Uganda. However, there is a marginal decline in cases of poverty in rural areas taking comparison of 2006 and 2014 statistics. The statistics also show that Kenya has the lowest disparity between the rural and urban poor while Uganda has the highest.

Figure 2: Rural and urban Poverty in Kenya, Tanzania and Uganda



Source: Household Economic Surveys

Conceptual framework and estimation strategies

The study follows Suri's (2011) and Asfaw et al (2012) methodologies, where we shall examine whether the yield returns to adopting agricultural technology vary across a random sample of farmers, such that high average returns to the technologies are accompanied by low returns for the marginal farmer. Allowing heterogeneity in returns to play a role in the adoption decision implies that the knowledge of average returns is not enough to understand the adoption decisions across a sample of farmers. Our study examines the adoption of agricultural technologies in East Africa within a framework of heterogeneous returns where a farmer's expected benefits from the technology are allowed to be correlated with his decision to adopt the technology. The study therefore model technology adoption as a selection process where yields may be heterogeneous and expected benefits to the technology may drive adoption decisions in each period. This allows for household specific heterogeneity in returns and hence controls for selection via comparative advantage differences across households.

Using this model, there are technology options available to farmers: to plant either improved seed or a traditional variety. The production function at any point in time for a farmer is of Cobb-Douglas form as follows:

$$Y_{it}^{H} = e^{\beta_t^H} \left(\prod_{j=1}^{k} x_{ijk}^{\gamma_j^H} \right) e^{\mu_{it}^H} \quad (1)$$

$$Y_{it}^{N} = e^{\beta_t^N} \left(\prod_{j=1}^{k} x_{ijk}^{\gamma_j^N} \right) e^{\mu_{it}^N} \quad (2)$$

where the outcome variables Y_{it}^{H} and Y_{it}^{N} , are the yields (output per acre) at a time t when farmer i uses improved seed or traditional variety respectively. Throughout, H is used to represent the use of improved seed and N the use of traditional variety. The X_{ijt} represents various other inputs (where j indexes the input), such as fertilizer, labor, rainfall, etc., as well as province dummies. The indexing of X_{ijt} by both i and t is quite general as some of the inputs may only vary by households (such as average long term rainfall). The production functions for improved seed and traditional variety have different parameters on the inputs, i.e. the X_{ijt} is have different coefficients in the production functions (indicated by H and N) to allow for complementarily between the variety used and the inputs. Finally, the μ_{it}^{H} and μ_{it}^{N} are sector-specific errors that may be the composite of time-invariant household characteristics and time-varying shocks to production.

In addition, households also have consumption decisions. Adoption and inputs uses are the outcomes of optimizing by heterogeneous agents. The optimization is dependent on constraints budget related to their inputs. The households are assumed to maximize their utility function subject to the budget constraints. Using this random utility framework, the households adopt technology if the adoption their utility levels increase. The difference between the utility from adoption (U_t) and U_{nt}) of adoption of technology is given as O_t^* such that the utility maximizing farm household *i*, will chose to adopt an improved variety, if the utility gained from adopting is greater than the utility of not adopting. These utilities are unobservable and the variables that related to utility can be expressed using a latent variable model.

$$O_{it}^{*} = \beta x_{it} + \mu_{it} \quad \text{with } O_i \begin{cases} 1 \\ 0 \end{cases} if\ O_i > 1\ and\ otherise\ 0. \quad (1)$$

where O is a binary indicator variables that equals 1 if a farmer uses improved variety seeds and zero otherwise. β is a vector of parameters to be estimated, *X* the explanatory variables, t is the years, and *u* is the error term. Welfare indicators can affect technology adoption in developing countries because of input and output markets missing or being imperfect. As a result, per adult equivalent unit (AEU) non-oxen assets, per AEU oxen and per AEU farm size are included as wealth indicator variables in the model. According to Asfaw et al (2012), these variables provide production services and resources for use by the farmers in the farm and increase the likelihood of technology adoption. Others variables included are households characteristics and human capital, contact with government extension agents, access to farm activities, access to credit, practice of soil and water conservation, distance to the market among others, media, member of farm association. According to the literature focusing on adoption of technology, these variables have found to be important (see Foster and Rosenzweig, 2010; Doss 2006). Dummy variables are included for different crops, regions and years.

The consumption expenditure per AEU is an important variable in this study. The determinants of this welfare variable are related to some of the observed variables. As a result, there is an endogenous problem, which means that we could have biased estimates. The decision to adopt technology or not might not be voluntary and may be based on individual self-selection. Therefore, the farmers that adopt might have different characteristics compared to those who do not adopt. These unobserved characteristics may affect the adoption decision and welfare outcomes. Given that we have sample selection and endogeneity, the study uses an endogenous switching regression model that accounts for both endogeneity and sample selection (Di Falco et al. 2011).

Endogenous switching regression model

Using Di Falco et al. (2011) and Asfaw et al (2012), a model can be developed where the welfare outcome of the households has two regression equations and a criterion function O_i that determines which regime the household faces.

$$O_{it}^{*} = \beta X_{it} + \mu_{it} \qquad (2)$$

Regime 1: $Y_{1it} = \alpha_1 Z_{1it} + e_{1it} \quad if\ O_{it} = 1$ (3)

Regime 2: $Y_{2it} = \alpha_{12} Z_{2it} + e_{2it} \quad if\ O_{it} = 0$ (4)

where O_i^* is the unobservable or latent variable for technology adoption at time *t*, O_i is its observable counterpart, Z_i are non-stochastic vectors of observed farm and non-farm characteristics determining adoption, Y_i is household consumption expenditure per AEU in regimes 1 (adopters) and 2 (non-adopters), Z_i represents a vector of exogenous variables thought to influence consumption expenditure and u_i & e_i are random disturbances associated with the adoption of improved technology and welfare outcome variable, respectively. The consumption expenditure function includes covariates related to technology adoption.

While previous studies estimate each equation separately (Carter, 1989; Feder et al., 1990; Carter and Olinto, 2003; Petrick, 2004; Guirkinger and Boucher, 2008), the FIML method estimates both selection and outcome equations simultaneously, generating consistent standard errors (Lokshin and Sajaia, 2004 and Ali et al. 2014). Both Wooldridge (2006) and Greene (2008) characterize the FIML as generally the most efficient estimation strategy to estimate models with endogenous switching providing there are no specification errors. In addition, there is a probability that a household to adopt improved technology needs to be with contact with government extension workers or non-governmental extension workers who can help them to access information on these seed varieties. As a result, we use these as selection instruments. These kinds of variables have been used by both Di Falco et al. (2011) and Asfaw et al (2012).

Datasets and description analysis

Datasets

Our study utilizes the panel data from the World Bank's Living Standard Measurement Survey-Integrated Surveys on Agriculture (LSMS-ISA) which at the moment is available for Uganda and Tanzania. These households were previously interviewed in the 2005/2006, 2007/2008, 2009/2010, 2011/2012 and 2013/2014 in Uganda National Household Survey and 2007/2008, 2010/2011 and 2011/2012 for Tanzania National Household Survey. This sample is representative at the national, urban/rural and main regional levels. The household survey project is funded by the Bill and Melinda Gates Foundation as well as other donors in the country and is implemented by the Development Economics Research Department of the World Bank in close collaboration with the national statistical offices. The data are unusually rich. They are nationally representative; they are geo-referenced and contain detailed plot level information on agriculture as well as many modules on non-agricultural facets of people's livelihoods (including employment, income, consumption, shocks, assets, nutrition).

Sampling and Survey Design

For Tanzania, sample for the first round was 3,265 households and had sample representation for the nation as a whole and provides reliable estimates of key socioeconomic variables for mainland rural areas, Dar es Salaam, other mainland urban areas, and Zanzibar. In the second round, all original households were targeted for revisit. Those members still residing in their original location were re-interviewed, and all adults who had relocated were tracked and re-interviewed in their new location with their new households. The sample size for the second round subsequently expanded to 3,924 and for the third round was a sample size of 5,015 households. In Uganda, the first round of the sample had about 3,200 households, all of whom had been previously interviewed as part of the 2005/2006 Uganda National Household Survey (UNHS). The sample was a representative at the national, urban/rural and main regional levels (North, East, West and Central regions). This sample was visited for two consecutive years (2009/10 and 2010/11). The surveys focus on community-level questionnaire with the following units of analysis: individuals, household, and communities.

Descriptive Statistics

In this paper, adopters are classified as farmers that planted improved seeds in any crop irrespective of the area planted. The non-adopter use traditional seeds in their farms. Literature shows that many adopters do not fully allocate their land to improved varieties as they also grow traditional varieties (Asfaw et al. 2012). However, in this paper we would like to see if households that adopt improved seeds do better than the households that adopt in terms of their welfare. Therefore, the adoption decision is models as binary variable at the households' level. As shown in table 1 below, a lot households in both Tanzania and Uganda tend prefer traditional seeds.

Table 1: Tanzania and Uganda: Improved Vs Traditional Seeds

Year	**Tanzania**				Year	**Uganda**			
	Yes		No			Yes		No	
	Freq	%	Freq	%		Freq	%	Freq	%
2008	169	8.71	1,771	91.29	2005	131	6.69	1,889	93.51
2010	191	37.67	316	62.33	2009	96	17.65	448	82.35
2012	505	20.92	1,909	79.08	2010	83	15.72	445	84.28
					2012	174	14.01	1,068	85.99
					2014	89	7.50	1,097	92.50

In Tanzania, the households that use traditional seeds have drop from 91 percent in 2008 to about 62 percent in 2010. This was mainly due to Tanzanian government launch of National Agriculture Input Voucher Scheme to give farmers 50% subsidy on fertilizers and improved maize seeds in 2009. This was complemented by the immense support given by the government to agricultural research institutions and extension services to develop and disseminate improved technologies to farmers so as to enhance their welfare through improved crop and livestock production (Lyimo, 2014). However, some of the households seen to have moved back to traditional seeds as shown in 2012, 79 percent households using traditional seeds. In Uganda, there was drop in the households that used traditional seeds from 93 percent in 2005 to 82 percent in 2009. After that, most households have continued to use traditional seeds which were more than 92 percent in 2014.

This trend does not appear to be different when comparing urban and rural areas in the two countries in Figure 3 and 4 below. However, the households in the rural areas planted improved seeds compared to the urban areas. In Uganda, there are few households in the plant improved seeds compared to Tanzania. Very few households in urban areas in Uganda use improved seeds.

Figure 3: Rural vs Urban adoption of improved seed varieties for Tanzania

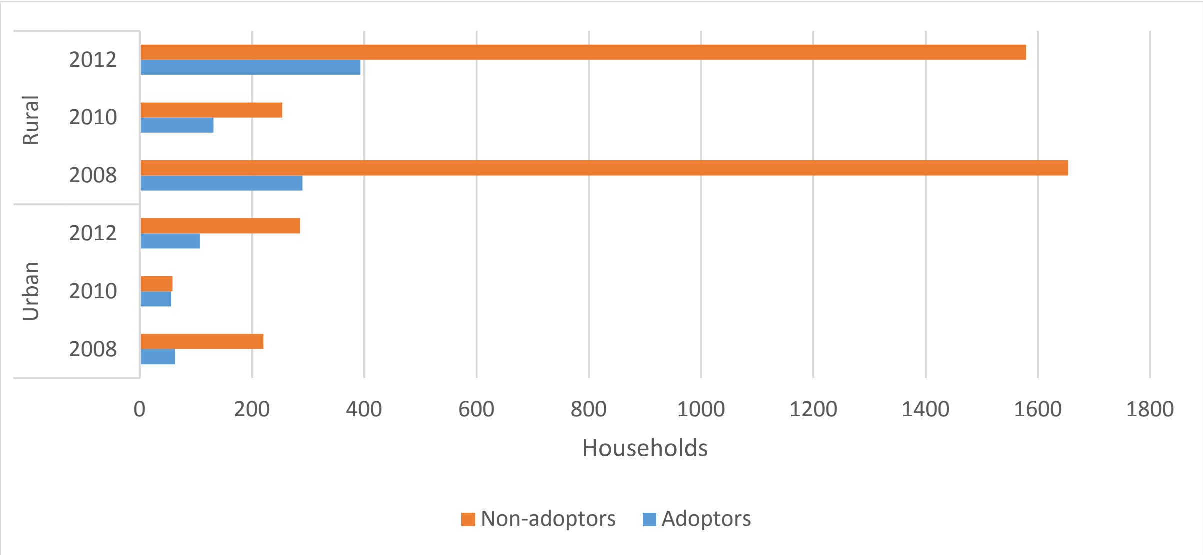
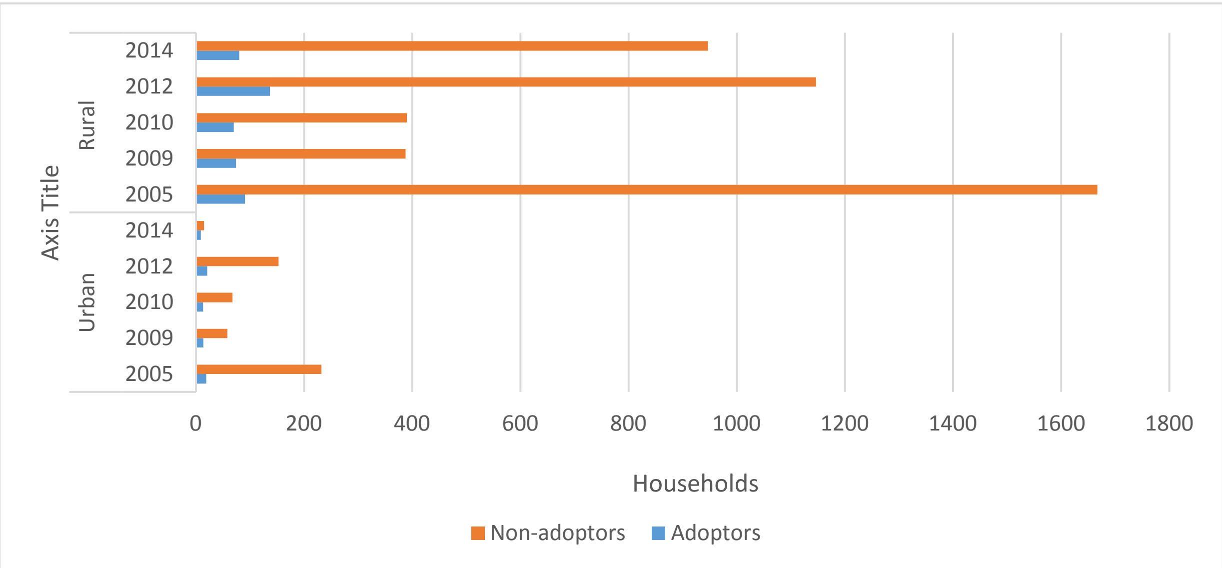


Figure 4: Rural vs Urban adoption of improved seed varieties for Uganda



Therefore, in East Africa, many farmers are slow to adopt technology innovations. According to Doss (2006), the main reason that farmers do not adopt improved technologies is mainly due to the fact that they are not aware of the benefits of such technologies. In addition, sometimes the technologies are not available or not available at the times they need them. Moreover, these technologies might not be profitable given the complex set of decisions that farmers make about how to allocate their land and labour in their farms. As indicated earlier, low farmer's adoption of technology in East Africa is mainly due to lack of farmer's awareness of such technology, availability and marketability of the improved seeds which is also very low (ASARECA, 2012; RLDC, 2009).

The study focuses on the following variables for both adopters and non-adopters in the two countries as shown in Table 3 below. The first is the consumption per adult equivalence, which helps us to see the impact of technology on welfare. Technology adoption can help in increasing productivity and consumption expenditure which affects farmers' welfare. This variable was used by Asfaw et al. (2012). However, other authors use per capita incomes such as Mendola, 2007; Kassie et al., 2011). AEU consumption expenditure helps us to have more reliable welfare indicator and less prone to measurement errors than total household income. According to Asfaw et al. (2012), the household income indicates the ability of the household to purchase its basic needs of life while per AEU expenditure reflects the effective consumption of households and therefore provides information on food security status of households. In the datasets, the consumption variable included food staff (such as cooking flour, sugar, beverages, grains, vegetables, animal products and other food items), Energy (electricity, Kerosene, gas), clothing (such as clothes, beddings, shoes) and social activities like medical bills, education, church & local organization contributions.

Table 3: Descriptive Summary of the Explanatory variables used in the estimations

Explanatory variables (Means)	**Tanzania**			**Uganda**		
	Adopters N=2344	Non-adopters N=2531	t-test (Chi-square)	Adopters N=563	Non-adopters N=5148	t-test (Chi-square)
Outcome variable						
Consumption per AEU(USD)	285.09	94.51	26.05***	0.17	0.16	1.14
Households Characteristics variable						
Age of household head(Male=1)	44.43	44.89	17.94***	45.24	45.65	0.94***
Gender of household head(Male=1)	0.48	0.48	0.61	1.36	1.41	-10.8***
Household head education(years)	1.85	2.11	21.82***	-	-	-
Active family labour force(AEU)	4.05	2.13	2.24*	2.3	2.2	5.04***
Dependency ratio	0.41	0.46	3.29**	0.63	0.67	-12.5***
Households wealth and farm characteristics						
Animals per AEU(number)	0.02	0.08	-1.66*	0.1	0.1	22.7***
Value of farm assets per AEU (USD)	1.28	1.38	-19.12***	0.02	0.01	-2.77**
Farm size per AEU (ha)	0.4	0.43	2.98***	0.88	1.34	5.1***
Access to off-farm activities(yes=1)	1.86	1.91	9.97 ***	0.47	0.31	9.8**
Farming main occupation(yes=1)	0.44	0.44	19.03***	0.18	0.16	62.35***
Practice of soil and water conservation(yes=1)	1.86	1.92	2.9**	2.79	2.79	16***
Institutional and access related variables						

Contact with government extension agents(number)	0.16	0.25	30.66***	0.07	0.056	22.72***
Contact with Non-governmental extension agents(number)	1.77	6.17	899***	0.08	0.06	26.69**
Access to credit(yes=1)	1.98	1.99	(1.73) *	0.84	1.38	8.48
Access to media (yes=1)	-	-	-	0.03	0.06	0.9
Distance from the farm to the market(KM)	9.36	6.71	62***	10.15	7.9	0.32**
Improved crop variety	1.06	1.14	14.00***	1.51	0.37	4300***
Member of farm association(yes=1)	-	-		0.21	0.09	-1.39
Maize	0.42	0.44	3.6***	0.06	0.05	-1.8
Rice	0.09	0.08	562.1**	0.01	0	2.1
Cassava	0.06	0.08	95***	0.06	0.05	0.5
Bananas	0.05	0.04	13.45***	0.03	0.01	18.13***
Other Crops	0.25	0.22	1.1***	0.04	0.1	7.47**

Note Statistical Significance at 99(***), 95% (**) and 90% (*) confidence levels.

The results show that the mean age of adopters in Tanzania is approximately 44 years and that of non-adopters is close to 45 years. For the case of Uganda, the mean age of adopters is nearly 45 years and approximately 46 years for non-adopters. This shows that in both Tanzania and Uganda, adopters are relatively younger than non-adopters implying that as the age of the farmer increases, there are chances of developing resistance to the adoption of new technologies. Active family labour force results for two countries indicate that generally, adopters have more active labour force than non-adopters. In Tanzania, the mean labour force for adopters is 4.05 and 2.11 for non-adopters while for Uganda, the mean labour force for adopters stands at 2.3 and 2.2 for non-adopters. This are inferred to mean that new seed/crop varieties require additional labour force. Asfaw et al. (2012) and Mukasa (2016) found similar results in Tanzania-Ethiopia, and Tanzania-Uganda respectively.

The average farm size in hectares for adopters is 0.4 and 0.88 while that of non-adopters is 0.43 and 1.34 for Tanzania and Uganda respectively, indicating that non-adopters cultivate a relatively bigger land than adopters. This could be interpreted to mean than new technology comes with an extra cost and hence the reduction in area of land cultivated. These findings are however not consistent with Kiiza et al. (2011) and Mukasa (2016) who observed that the average size of the farm for adopters is larger than that of non-adopters. Access to non-farm activities, farming as the main economic activities and availability of various improved crop varieties increase the likelihood of adopting new technology in Uganda but not in Tanzania according to the summary results. Similarly, belonging to farmer's association and also being able to access media, is more likely to induce a household member adopt modern farming technologies.

Then mean of the contact between adopters and government extension agents is 0.16 while that of non-adopters is 0.25 in Tanzania, while in Uganda, adopters have an average mean contact with government extension agents of 0.07 and 0.056 for non-adopters. This means that government extension agents have an influence on farmers with respect to the adoption of modern farming methods in Uganda and not Tanzania. A similar observation in noted in the case of non-governmental extension agents. Turning to crops, our analysis show that the adoption rate of improved seed verities in higher in Uganda than in Tanzania according to the results of the selected dominant crops. For example, in Uganda the average mean for adopting maize, rice, cassava and bananas is higher than that of non-adopters while in Tanzania, only rice and bananas recorded higher means among the adopters.

The average consumption expenditure in both countries in higher among the adopters than non-adopters. The results show that the mean annual expenditure for an adult household member in Tanzania is US$ 285 for adopters against US$ 94 for non-adopters while in Uganda, adopters spend about US$ 0.17 against non-adopters who spend an average of US$ 0.16. Kassie *et al.* (2011), Amare *et al.* (2012), Asfaw et al. (2012) and Mukasa (2016) established similar results.

Descriptive statistics further indicates that farmers who plant improved seed varieties get more yields than non-adopters in the two countries. On average, an adopter in Uganda, harvests 12.85 kg of a crop per hectare against 7.14 for non-adopter while in Tanzania an adopter harvests 0.71 kg/ha against 0.58 for those who use local seeds.

Table 4: Total Economic Benefits of the households in Uganda and Tanzania

Uganda: Total Economic Benefits						
	Total		**Local Seeds**		**Improved Seeds**	
	Mean	SD	Mean	SD	Mean	SD
Yields in Kgs (ha) ("000")	16.34	20.81	7.14	207.93	12.85	78.1
Gross Production per ha(USD)	19.41	108.34	17.09	98.56	32.83	171.49
Variable costs per ha (USD)	13.81	65.88	11.95	72.97	27.55	86.41
Profit per ha(USD)	5.57	42.46	5.14	25.59	5.28	85.08
Tanzania: Total Economic Benefits						
	Total		**Local Seeds**		**Improved Seeds**	
	Mean	**SD**	Mean	SD	Mean	SD
Yields in Kgs (ha) ("000")	0.65	1.32	0.58	0.99	0.71	1.76
Gross Production per ha(USD)	97.61	189.09	68.51	90.75	125.88	266.57
Variable costs per ha (USD)	242.26	11525.36	770.53	23032.21	284.34	8314.01
Profit per ha(USD)	-144.65	-11336.27	-702.02	-22941.46	-158.46	-8047.44

Estimation results and discussion

In the study, the first objective was to look at the determinants of technology adoption in the two countries. We focus on the improved seeds varieties. To do this, we applied probit and linear fixed effects models and the results are in table 4 below. In a pooled probit, the entire cross-period correlation is assumed away and the panel is treated essentially as a cross-section. The random effects model maintains the homoscedasticity (unit variance) assumption but extends the pooled model by allowing the cross-period correlation, in their case to be equal for all period pairs. The fixed effects probit estimator can be severely biased owing to the incidental parameter problem. To avoid this problem, we use the linear probability model (Neyman & Scott 1948; Angrist & Pischeke 2008: 166). The Hausman test is significant at the 1 percent level at 1050.55 and 4206.15 for Tanzania and Uganda respectively. This implies that there is significant correlation between the time-invariant households' specific effects and the explanatory variables. Under such circumstances, the fixed effects model is preferred and will form the basis of the results.

The results as presented in Table 4 provide factors determining the adoption of improved seeds among farmers in the two countries. The dependent variable is whether to adopt or not, where the dependent variable takes the value of 1 and 0 otherwise. Results indicate that life-cycle plays a significant role in the technology adoption decision in Tanzania. The propensity to adopt new seed varieties tend to increase with the age of the household members 44 years before it starts to decline.

Table 4: Determinants of technology adoption (improved seeds) in Tanzania and Uganda using probit and linear probability models

Variables	Adoption decision (o/1) Improved Seeds in TZ	Adoption decision (o/1) Improved Seeds in TZ	Adoption decision (o/1) Improved Seeds in UG	Adoption decision (o/1) Improved Seeds in UG
	Probit	**LPFE**	**Probit**	**LPFE**
Age of household head	-.0027(0 .0033)	.0003(0,0003)	-.0179(0 .002) ***	-.0002(0.000)
Age of household head square	-.000012(0 .00004)	-.0009(0.003) **	.00019(0.00003) ***	-0.000(0.000)
Education of the head	-.035(0 .0100) ***	-.004(0 .001) ***	-----	
Family size in AEU	.0246(0 .0091) **	-.000(0.000)	.0452(0 .007) ***	.0012(0. 0006)***
Gender of household head	.0045(0 .0383)	-.001(0.0033)	-.326(0 .024) ***	.004(0.003)
Farm size per AEU	2.270(0 .308) ***	.312(0 .021) ***	.283(0 .016) ***	.040(0.0016) ***
Farm equipment per AEU	.475(0 .0393) ***	.0013(0 .001)	-0.000(0. 000)	-0.000(0.000)
Animals owned	-.0620(0 .0263) **	-.001(0.001)	.355 (0 .055) ***	-.044(0.068)
Distance to the market	.0151(0 .0023) ***	.005(0.0003) ***	.0054 (0 .0013) ***	0.000(0.000)
Contact with Government extension agents	.727(0 .149) ***	-.016().002) ***	.200(0 .052) ***	.028(0.007) ***
Contact with other extension agents	.013(0 .0039) ***	.007(0.0003) ***	.277(0 .052) ***	.0063(0.008)
Practice of soil and water conservation	.952(0 .040) ***	.242(0.002)	.103 (0 .0052) ***	.115(0.004) ***
Number of improved seed varieties	0.00(0.00)	.069(0.010) ***	.728(0 .034) ***	.263(0.005) ***
Farmer association with hh head	-.0147(0 .292)	.031(0.021)	.108 (0 .031) ***	.015(0.004) ***
Access to credit	-.187(0 .090) **	-.046(0.007) ***	.176(0 .014) ***	.0192(0.0016) ***
Access to off-farm activities	-.029(0 .028)	.011(0 .003) ***	-.351(0 .025) ***	-.009(0.006)
Access to media (TV viewing)	----		.195(0.105)	.046(0.01) ***
Maize	1.159(0 .073) ***	.095(0.007) ***	.378 (1.187) ***	.219(0.056) ***
Rice	1.375(0 .147) ***	.0389(0.011) ***	0.00(0.00)	-.0003(0.039)
Cassava	-.332(0.089) ***	-.041(0.012) ***	-.631(1.161) ***	.172(0.071) **
Bananas	-.456(0 .0972) ***	-.033(0.014) **	-.102(0.096) ***	.032(0.016) **
Other Crops	.462(0 .077) ***	.01(0.011)	-.069(0 .097) ***	.017(0.009) *
Rural	0.00(0.00)	.016(0.019)	.479(0.186) **	.028(0.010) ***
Regions				
Dar es Salaam	-.708(0 .081) ***	-.116(0.016) ***		
Lindi	.517(0 .085) ***	.178(0.040) ***		
Mtwara	.308(0 .071) ***	.022(0.030)		
Shinyanga	-.350(0 .085) ***	.036(0.032)		
Kampala			3.156(82.91)	.067(0.021) ***
Central			4.072(82.91)	.035(0.018) *
Eastern			4.369(82.91)	.117(0 .019) ***
Northern			4.61(82.91)	.300(0.019) ***
Western			4.408(82.91)	.022(0 .019)
Year Effects	Yes	Yes	Yes	Yes
Constant	-1.536(0 .0954)	.235(0.012) ***	-6.346(82.91)	.042(0.023) *
Number of observations	36,588	36,588	43,714	43,714
Log likelihood	-2653.8803		-7127.72	
LR chi2(21)	9408.66***		7947.89***	
Hausann Test		1050.55***		4206.15***
Pseudo R2	0.6393	0.5984	0.358	0.3286

Note Statistical Significance at 99 (***), 95% (**) and 90% (*) confidence levels. The number in brackets show standard errors.

Even though age coefficient is not significant in the case of Uganda, its negative sign could point to a similar situation like that of Tanzania. In Tanzania, education of household head is negative and significant at the 1 percent level. The household heads that have more education in Tanzania do not use new seed varieties. These results are different from Asfaw et al. (2014) for Tanzania for pigeon pea varieties. The number of adult household members is found to have a positive influence on the adoption of improved seed varieties in both countries. However, it is only significant at the 1 percent level in Uganda. This result shows that the adoption of improved seed varieties attracts more labour force for ploughing, weeding and harvesting as well as thievery control for some crops. While these findings are consistent with Odame et al. (2013), they contradict Mukasa (2016) who found negative but significant correlation between the adoption of improved seed varieties and the number of adult members in the household.

Farm characteristics play an important role in influencing technology's adoption behavior of the household head. In both Tanzania and Uganda, the probability to adopt new seed varieties increases with an increase in the size of the plot cultivated. These findings are in line with Suri (2011); Asfaw et al. (2014). This implies that the demand for hybrid seeds in both countries increases with an increase in the size of the land cultivated.

Literature reveals that adoption of new technologies is sometimes affected by the level of awareness of such technologies. The study considered distance of the household from the market, contact with government and non-governmental extension services, and accessibility to media as proxies for accessing knowledge of the available improved seed varieties and their characteristics. Our findings show that contact with both government agencies is important for adoption of technology in both countries and is significant at the 1 percent level. The distance to the market and non-governmental extension agencies seems to be more important for Tanzania than Uganda for the adoption of new technology. It is significant for Tanzania at the 1 percent level. Although the coefficient for the farm-market distance is significant, its correlation to the adoption of improved seed varieties in negative. This observation contradicts Shiferaw et al., (2008) and Mendola (2007). Access to media was also found to positively correlate with adoption of agricultural technology in Uganda. Similar findings were reported by Asfaw et al., (2012) for Ethiopia & Tanzania, Shiferaw et al., (2008).

Similarly, practice of water and soil conservation positively influences the decision to adopt improved seed varieties both countries, but in Uganda this significant at the 1 percent level. The objective of soil erosion is to enhance the quality of soil in order to improve productivity and hence this finding is consistent with Moyo et al. (2007) who found that in arid and semi-arid lands in Kenya, areas with better soil quality are more likely to adopt improved seeds and use of chemicals (fertilizers and pesticides).. In addition, the households that have the head of the household involved in a farmers association tend to adopt new technology. Moreover, the number of improved seed varieties is important for the adoption of technology in both countries. While credit is important for the households in adoption of technology in both countries, it is negative and significant in Tanzania but positive and significant in Uganda. This result contrasts with results by Asfaw et al. (2014) for Tanzania and Ethiopia. The access to off-farm activities seems to be important for adoption of technology compared to Uganda but not in Tanzania.

The main crop that is positive and significant at the 1 percent level in both countries is maize. The other important crop in Tanzania is rice which is positive and significant at the 1 percent level. However, cassava and bananas negative and significant at 5 percent. This might suggest that there is little technology adoption in these two crops. In Uganda these two crops are significant and positive at the 5 percent level. The study also estimated regional variations in the adoption decisions. Thus, regional dummies were included in the model and results indicate that adoption decisions vary across these regions. For Tanzania, two regional Dar es Salaam and Lindi are statistically significant. The negative sign for Dar es Salaam indicates that farmers in that region have the highest propensity to adopt improved seed varieties as compared to the other districts. This means that awareness on the agricultural technology probably differs from one region to the other. On the other hand, only one region that is not significant and positive in Uganda which is western part.

In summary, the most determinants of adoption of new seed varieties in both countries are farm size, contact with government agencies, number of improved seed varieties and credit. Other determinants that are important Tanzania include age squared education of the households head, distance to the market, contact with other extension agents and access to off-farm activities. In Uganda other determinants for adoption of new seed varieties include family size, participation of soil and water conservation, farmers association and access of media.

Welfare effects of technology adoption

The correction between adoption of seed varieties and households' outcomes such as consumption expenditure is not easy. We use endogenous switching model for this purpose. In addition, the study uses contact with government extension workers and non-government extension workers for selection instruments. Using a full information maximum likelihood estimates in the endogenous switching regression model can control for unobservable section bias. The results are in table 5 and 6 below for Tanzania and Uganda respectively. The two columns present the consumption expenditure functions for both non-adoption households and those that used improved seed varieties. To analyse the consumption per AEU, different variables were used related to households head characteristics, gender, dependency, education levels, assets, regions and where the households were in the rural areas. The results from the models show that the estimated coefficient of correlation between the improved seed varieties and the consumption expenditure function is negative and significantly different from zero. This is similar to the results by Asfaw et al. (2014) for both Tanzania and Ethiopia. The results suggest that both observed and unobserved factors affect the decision to use improved seeds and welfare outcomes given their adoption decision. In addition, significant of the correlation between improved seeds varieties model and the welfare of the adopters indicate that there is self-selection in the adoption of improved seeds varieties. Moreover, the difference between the coefficients of adoption and non-adopters models means there is heterogeneity in the sample. The results also show that the households that had improved seeds varieties has higher consumption expenditure compared to who did not. This is true for both countries.

Table 5: Full information maximum likelihood estimates of the switching regression model. Dependent variable: new variety of seeds adoption and log consumption expenditure per AEU for Tanzania.

	Non-Adoption=0		Adoption=1	
Variable	Coef.	Std. Err.	Coef.	Std.Err
age	0.01***	0.00	0.01***	0.00
age2	0.00***	0.00	0.00***	0.00
Gender	-0.03	0.02	-0.02	0.05
Dependency ratio	0.01	0.02	-0.06	0.07
Hhh years of school	-0.01*	0.00	-0.01	0.01
Farm size AEU ha	-0.07	0.21	-0.34	0.28
Log value offarm equipment per AEUUSD	0.58***	0.02	0.54***	0.06
Animals owned perAEU	3.18***	0.55	4.44***	1.59
Farmerassociation1	-0.22**	0.10		
Daresalam	0.56***	0.02	0.74***	0.09
Lindi	-0.22***	0.05	-0.14	0.10
Mtwara	-0.12***	0.04	0.08	0.09
Shinyanga	-0.07*	0.04	0.15	0.11
Constant	7.05***	0.16	6.95***	0.47
rho0	.51			
rho1	-.32			
LR test of indep. Eqns (Chi(2)		32.45***		

Note Statistical Significance at 99 (***), 95% (**) and 90% (*) confidence levels. The number in brackets show standard errors

Table 6: Full information maximum likelihood estimates of the switching regression model. Dependent variable: new variety of seeds adoption and log consumption expenditure per AEU for Uganda.

	Non-Adoption=0		Adoption=1	
Variable	Coef.	Std. Err.	Coef	Std. Err
age	0.01***	0.00	0.02**	0.01
age2	0.00***	0.00	0.00***	0.00
Gender	0.01	0.02	0.00	0.09
Dependency ratio	-0.08***	0.03	-0.69***	0.17
Farm size per AEU ha	-0.18***	0.04	-0.01	0.03
Farm equipment owned per AEU	0.00	0.00	0.00	0.00
Off-farm activities	0.19***	0.01		
Kampala	1.22***	0.12		
Central	0.41***	0.06	0.01	0.22
Eastern	0.01	0.06	-0.31*	0.18
Northern	-0.13**	0.06	-0.81***	0.17
Western	0.22***	0.06	-0.68***	0.25
Rural	-0.53***	0.02	-1.03***	0.12
Constant	1.20***	0.07	1.98***	0.37
rho0	.51			
rho1	-.32			
LR test of indep. Eqns (Chi(2)	42.84***			

Note Statistical Significance at 99 (***), 95% (**) and 90% (*) confidence levels. The number in brackets show standard errors

Conclusion

This paper focused on the determinants of adoption of improved seed varieties in Tanzania and Uganda. In addition, the study looked at the impact of improved seeds varieties on welfare using consumption expenditure. The study used a new database from the World Bank's, Living Standard Measurement Survey-Integrated Surveys on Agriculture (LSMS-ISA). Panel data is available for both Uganda and Tanzania. By using this approach, the study provides fresh insights into the constraints hindering agricultural technology adoption as well as the impact on household welfare. The determinants of adoption are based on both probit and linear probability models. The impact of adoption on welfare is based on endogenous switching model. This helps in estimating the true welfare effect on improved seed varieties by controlling for selection problem on production and adoption decisions.

The results from the study shows that in the determinants of adoption of new seed varieties in both countries include farm size, contact with government agencies, number of improved seed varieties and credit. Other factors that affect either Uganda or Tanzania include age, distance to the market, contact with other extension agents and access to off-farm activities, family size, participation of soil and water conservation, farmers association and access of media. Given that countries tend to be different, there are variables that important for all countries, but there are many variables that tend to be specific for each country. The results from the endogenous switching model show that the households that use improved new seed varieties tend to be different from those that do not. In addition, the households that use these varieties tend to have higher consumption expenditure even after controlling for observed and unobserved factors. The results show the potential of improved seeds varieties in helping households in especially in rural areas increasing their welfare.

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