Discussion Paper Series
RIEB
Kobe University

DP2015-06

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February 13, 2015

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This Draft: 1st February 2015

Abstract

The present study examines the relationship between farm size, agricultural productivity and access to agricultural extension programmes in reducing poverty and vulnerability drawing upon LSMS panel data in Uganda in 2009-2012 covering three rounds. We first estimate household crop productivity using stochastic frontier analysis that can allow for stochastic shocks in the production function. Second, we have found a negative association between farm size and agricultural productivity for output per hectare, intensity of land use and net profit per hectare, but not for technical efficiency, suggesting that smallholders are generally more productive than large-holders. It is misleading to consolidate land or neglect smallholders in favour of large farmers on the grounds of economy of scale in crop production. Third, the effect of different types of agricultural extension programmes - namely NAADS or government, NGO, cooperatives, large farmer, input supplier and other types extension service providers - on the crop productivity is estimated by treatment effects model which controls for the sample selection bias associated with household participation in the agricultural extension as well as unobservable factors at household levels. It is found that participation in agricultural extension programs significantly raised crop productivity only in a few cases, but increased household expenditure per capita in all cases. Fourth, a substantial share of households was found to be vulnerable and education was found to be the key to reducing poverty and vulnerability. Finally, improvement in agricultural productivity reduces static poverty, but does not lead to reduction in household vulnerability. Agricultural policies tailored to local needs, such as agricultural extension programmes, should be thus combined with poverty or vulnerability alleviation policies targeting smallholders or the landless households.

Key Words: Agricultural Productivity, Farm Size, Agricultural Extension, Poverty, Vulnerability, Treatment Effects Model, Uganda

JEL Codes: C21, C31, I32, N57, O13, O16

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Acknowledgement: This study is funded by the International Fund for Agricultural Development (IFAD). We are grateful to Dr Rui Benfica and Dr Constanza Di Nucci at SSD Division, IFAD, for their enthusiastic support and guidance throughout this study. We are also grateful to Prof. Raghav Gaiha and Prof. Takahiro Sato for their valuable comments. The views expressed are personal and not necessarily of the organisations to which we are affiliated or of IFAD.

Do Agricultural Extension Programmes Reduce Poverty and Vulnerability? Farm Size, Agricultural Productivity and Poverty in Uganda

1. Introduction

The purpose of this paper is to examine the relationship between farm size, agricultural productivity and access to agricultural extension programmes in reducing poverty and vulnerability drawing upon LSMS panel data in Uganda in 2009-10, 2010-11 and 2011-12. We will test whether agricultural extension programmes were effective in reducing poverty and vulnerability to derive policy implications. We also focus on the relationship between farm size and productivity to see whether smallholders have higher agricultural productivity than large holders.[1]

Many countries in developing countries -Sub-Saharan African countries in particular - still rely on agriculture as a leading force of economic growth and poverty reduction. This is reflected in the fact that poverty in rural areas dependent on the agricultural sector is generally higher than that in urban areas. For instance, in Uganda, poverty headcount ratio based on US$1.25 in rural areas was 42.7% (27.2%), while the headcount ratio in urban areas was14.4% (9.1%) in 2002 (2009) (Imai et al., 2014b). Regardless of the assumption made about the share of poor people in (net) migrants from rural to urban areas, the contribution of poverty reduction in rural areas to the aggregate poverty reduction in 2002-2009 was estimated to be more than 80%, reflecting the high level of rural poverty ratio in 2002. The aggregate poverty ratio has continued to decline in this period – 39.2% in 2002, 31.1% in 2005 (UBOS, 2009) and 24.5% in 2009 (Imai et al., 2014b and UBOS, 2009). About 85 percent of Uganda's population live in rural areas, while 80 percent of the poor living in rural areas are mainly dependent on subsistence agriculture as a main earning source for their survival. Agriculture is the third largest sector contributing about 21.8% to Uganda's GDP,

[1] The draft draws upon Ali and Deninger (2013), Hasan, Imai, and Sato (2012), and Imai et al. (2014a).

next to services and industry sector. However, despite the importance of agricultural sector in the economy and its large share, agriculture has not been used to its full potential for development in Uganda due to farmers' lack of access to farm production technology and information that would be necessary for increasing agricultural productivity (World Bank, 2008).

Gaiha (2014) criticised Collier and Dercon (2014) and emphasized the important role of agricultural sector in poverty reduction, for example, because (i) the argument in favour of promoting smallholders remains because of its poverty impact, even if nested within an overall growth strategy that makes agriculture important but not the key sector; and (ii) the large gaps also suggest that the process of labour movement from activities with lower productivity to higher productivity is inadequate.

Policy focus on smallholders as one of the main strategies for accelerating poverty reduction is important - as discussed in detail in Gaiha (2014).[2] As Fan et al. (2013) argued, the negative link between productivity and the land size implies more efficient agricultural production of smallholders. This could be explained by smallholders' more intensive use of inputs and the lower costs associated with supervising family labour on small farms compared with hired labour on larger farms (Fan et al., 2013), though Fan et al. also referred to other studies (e.g. Barrett et al., 2010) arguing that larger commercial farms have an advantage in terms of finance, technology, and logistics.

Using the household data in rural Rwanda in 2010/11, Ali and Deninger (2013) found a statistically significant negative relationship between farm size and agricultural productivity - defined as yield (or output per hectare) regardless of whether plot characteristics or household attributes are controlled for by econometric estimations - for both at holding levels

[2] Collier and Dercon (2014) questions the importance assigned to promoting smallholder agriculture as an important pathway out of poverty and refute the argument of WDR 2008 that stimulating agricultural growth is "vital for stimulating growth in other parts of the economy" and smallholders are at the core of this strategy (World Bank, 2007, p. xiii). See Imai and Gaiha (2014) and Gaiha (2014) for detailed critiques of Collier and Dercon (2014).

or plot levels. They suggested that more intensive labour use by smaller farms is a key underlying reason. In fact, the relationship disappears (but does not reverse) if profit or technical efficiency, rather than output is considered and labour inputs are valued at the market wage. In fact, profits per ha are virtually identical across different farm sizes, suggesting that farmers are economically rational in light of existing constraints (Ali and Deninger, 2013). The present study tests the same hypothesis in the context of Uganda, but while Ali and Deninger's work (2013) used annual cross-sectional data ours is based on three-year panel data.

In the empirical literature agricultural extension has long been grounded in the technology diffusion model that accounts for the transfer of improved agricultural technologies and information at the farm levels (Swanson et al., 1998). The model includes a range of functions, consisting pluralistic rural knowledge and information systems of agricultural production about, for instance, service delivery, problem-solving, and financing (Alext, et al., 2004). Agricultural extension operates in diverse social settings and it involves a range of actors and organizations, such as, central and local governments, NGOs and private providers (Anderson and Crowder 2000). Among these various providers, central government is the dominant stakeholder in formal agricultural extension which is designed to achieve primary functions of the technology diffusion model.

In recent years, agriculture in developing countries has undergone a series of reforms that aim at positioning the role of the market as a leading force to promote optimal resource allocation among the various economic activities (Diaz, 2004), which often led the private sector to take over some of the functions which were formerly performed by governments. The developing countries which are dependent on agricultural sector are more "liberalised" in reforming the public sector to adopt non-government extension systems, especially reform in some African countries that face budget constraints (Ndegwa, 2002).

In Uganda, public sector extension was accomplished in 2001 to improve the efficiency and quality of agricultural extension services through a decentralized, demand-driven and client oriented and farmer-led approach and those extension services operated under a new statutory semi-autonomous body called NAADS (World Bank, 2001). The NAADS was planned to ensure (i) shifting from large national bureaucratic structures, such as privatization of funding, delivery of extension, and decentralization of authority to lower levels of the government; (ii) involving the private sector in a way of delegation to NGOs, farmer organizations, and other grassroots control; and (iii) focusing on the issues, such as equity, empowerment, and sustainability as a wider agenda in addition to technology transfer (Bashaasha et al., 2011). Resources of central government were allocated at sub-national or regional levels, so were managed advisory services. This framework took the form of the Poverty Eradication Action Plan (PEAP) under which a multi-sectoral Plan for Modernization of Agriculture (PMA) was performed with the ultimate goal of poverty eradication (MAAIF, 2000). The NAADS approach was an attempt to respond to current pressures on agricultural extension to be more responsive to the needs of small scale farmers and the rural poor for the goal of reducing rural poverty.

Under the NAADS statute enacted by parliament in 2001, the public extension system in Uganda was gradually phased out and replaced by the private provider (or NGO sector) advisory system (Bashasha, et al., 2011, p. 14). In operational terms, this means that the private extension service providers were invited to take up information dissemination roles and investigate (i) whether there would be enough demand for the services among farmers in order to attract private providers, and (ii) what factors would influence farmers' demand for extension services. The shift from the public to private extension delivery under the NAADS approach was faced with a number of challenges, including whether and how effectively agricultural productivity would be raised, poverty would be reduced, and ultimately, livelihood would be improved. The system calls for new relationships, knowledge and skills among the key stakeholders from the private sector, farmers, farmers' cooperatives, input suppliers, and government as they strive to realize the ultimate goal of poverty eradication.

Bearing in mind these backgrounds, we will address the following research questions using LSMS data in Uganda for which we will derive rural and urban poverty estimates, drawing upon Ali and Deninger (2013) and Hasan, Imai, and Sato (2012);

(a) whether the agricultural productivity is negatively associated with land size;

(b) whether the smallholders have higher productivity than large-holders;

(c) whether agricultural productivity is negatively associated with poverty or vulnerability; and

(d) whether household access to agricultural extension programmes has reduced poverty and vulnerability and which type of agricultural extensions was the most effective in reducing poverty and vulnerability.

The rest of the paper is organised as follows. The next section briefly explains the data we have used for the econometric analysis. Section 3 provides detailed description of our econometric models. Section 4 summarises the results. The final section offers concluding remarks.

2. Data

The present study is based on the LSMS (Living Standard Measurement Survey) data set based on the Uganda National Panel Survey (UNPS) conducted by the Uganda Bureau of Statistics (UBOS) in 2009-2012, covering three rounds or crop-years, 2009-2010, 2010-2011, and 2011-2012. The survey was financially and technically supported by the Government of Netherlands, and the World Bank LSMS - Integrated Surveys on Agriculture (LSMS-ISA) project. Each round of UNPS was carried out over a twelve-month period on a nationally representative sample of households, which is a subsample of the 2005 Uganda National Household Survey (UNHS). To select the sample for the UNPS, the UNHS sample was divided into five strata (Kampala, Central, Eastern, Northern and Western). Within each stratum, enumeration areas (EAs) were selected using simple random sampling, but the probabilities of selection varied between strata. In Kampala, all UNHS EAs were selected to ensure sufficient sample size in that stratum. In the other four strata, the probability of selection ranged between 36 and 43 percent.

The basic objective of the survey is to provide the Government of Uganda with (i) the information required for monitoring the National Development Strategy and for facilitating monitoring poverty and service outcomes using the nationally representative household data, and (ii) a framework for conducting policy oriented analysis and for building relevant capacity. The survey is a multi-topic household survey covering a wide range of issues, including household composition and characteristics; item-wise crop production inputs and outputs; expenditure for both food and non-food items, health and education; and participation of households in agricultural extension programs. The survey also includes community level data on local infrastructure, public services, such as education, extension, health facilities, etc.

Descriptive statistics of major variables are found in Appendix 1. At the bottom, the summary statistics of the share of households that had access to different sources of extension programmes are shown. Our data suggest that an insignificant share (13.9%) had access to extension programmes from NAADS. The share of households with access to agricultural extension programmes or services from other sources is not high (e.g. 8.1% from NGO; 3.8% from Cooperatives; 1.6% from Large farmers; 2.3% from input suppliers and 3.3% from other sources). The distribution across different types of extension services has been further disaggregated by region and the results are shown at the bottom of Appendix 1. In all the regions (except Central Kampala and Kampala with a very small number of observations), extension programmes from NAADS has the largest share, to be followed by those from NGOs, with their magnitudes varying across different regions.

3. Methodology

3.1 Household crop productivity estimation

First, we will estimate crop productivity aggregated at household level to examine whether there is any room for further productivity improvement. We will also examine whether there is any negative relationship between farm size and the estimated productivity. For productivity estimation, Stochastic Frontier Analysis (Aigner et al., 1977 and Meeusen and Broeck, 1977) has been applied to allow for stochastic shocks in the production function. In the second step, treatment effects model has been used to examine if participation in agricultural extension influences outcome variables (namely, productivity estimated in the first stage, per capita consumption, and vulnerability) after taking account of sample selection associated with participation in the extension programmes. The stochastic frontier model allows for partitioning the stochastic error term into two components: systematic random error to account for statistical noise and an inefficiency component (Battese and Coelli, 1992). To fit stochastic production or cost frontier models for panel data, we estimate the parameters of a linear model with a disturbance generated by specific mixture distributions. The disturbance term in a stochastic frontier model is assumed to have two components. One component is assumed to have a strictly nonnegative distribution (namely, the inefficiency term) which represents the productivity, and the other component is assumed to have a symmetric distribution (i.e., the idiosyncratic error). Two different parameterizations of the inefficiency term are allowed - a time-invariant model where the inefficiency term assumed to have a truncated-normal distribution and the Battese-Coelli (1992) parameterization of time-effects in which the inefficiency term is modeled as a truncated-normal random variable multiplied by a specific function of time. In both models, the idiosyncratic error term is assumed to have a normal distribution. The only panel-specific effect is the random inefficiency term.[3]

For estimation, we consider Cobb-Douglas without restriction and with restriction (wherein homogeneity conditions are imposed on the parameters). The conventional production inputs are used in both specifications. The production function with Cobb-Douglas specification is specified as:

$$\ln Output_i = \beta_0 + \beta_1(\ln Land_i) + \beta_2(\ln Labor_i) + \beta_3(\ln Input_i) + \upsilon_i - u_i, \quad (1)$$

where ln*Output* is the natural log of total receipts obtained from output and by-products; ln*Land* is the natural log of the total land under cultivation; ln*Labor* is the natural log of total wage expenditures for labour; ln*Input* is the natural log of total expenditures for different inputs (seed, fertilizer, pesticides, water), i is the individual farmer and t represents year. Subscript t is omitted from each variable for simplicity.

The error term is decomposed into two components such as $\varepsilon_i = v_i - u_i$. The main idea of this decomposition is to derive, one pure random term (v_{it}) accounting for measurement errors and the effects which cannot be influenced by the firm such as weather, trade issues and access to materials. This component is assumed to be an identically symmetric and independently distributed error with a mean zero and variance σ_v^2. The other component is a non-negative one (u_{it}), measuring the technical inefficiency, i.e. the stochastic shortfall of output from the most efficient production (systematic departures from the frontier) (Battese and Coelli, 1995).

As the error term $E(\varepsilon_i) = -E(u_i) \le 0$, $\varepsilon_i = v_i - u_i$ is not symmetric, the estimation by

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[3] See Battese and Coelli (1992) for technical details.

OLS will provide consistent estimates of all parameters except the intercept term. But, OLS cannot isolate technical efficiency from the residual term. As the efficiency estimates fall between 0 and 1, normal distribution problem arises. The maximum likelihood (ML) estimation is a unified approach in such case of the normal distribution problem. The ML estimation selects values of the model parameters that produce the distribution most likely to have resulted in the observed data (i.e. the parameters that maximize the likelihood function). In ML estimation, the half-normal distribution works reasonably well and is most often used because the standard deviation of the distribution is able to concentrate efficiencies near zero or spread them out (truncated at zero) (Greene, 1990). Other empirical studies using different distributional assumptions for comparison showed that both rankings and efficiency scores are generally similar across distributions (Fujii, 2001; Street, 2003). Thus, we adopt the half-normal distributional assumption of the inefficiency component. Now, the technical efficiency of production for the i^{th} farmer can be computed as

$$TE_i = \exp\left(-u_i\right) = Y_i / Y_i^*, \tag{2}$$

where Y_i is its observed output and Y_i^* is its maximum possible output given the available inputs.

3.2 Relationship between farm size and agricultural productivity

Second, the relationship between farm size and agricultural productivity will be examined as in Ali and Deninger (2013). We will first present graphically the relationship between farm size (in terms of the area of cultivated land per household) and output per hectare (yield) for each year. Second, we will see the relation between farm size and intensity of labour use (the amount of labour used per hectare). Third, as an alternative specification, the relationship between farm size and net profit per hectare at holding will be examined. Finally, we will see the relationship between farm size and two different versions of estimates of technical efficiency to be derived by the model we presented in the last sub-section.[4] These specifications follow Ali and Deninger (2013). We will also derive the above relationships between farm size and different proxies for agricultural productivity after controlling for various household and other characteristics using robust OLS.[5]

3.3 Impact of agricultural policy (access to agricultural extension) on crop productivity and on poverty or vulnerability

The effect of agricultural extension programs on household level crop productivity is estimated. In non-experimental data, the sample households were not generally comparable between "treated" (participants) and "untreated" households (non-participants in the programmes) because of the non-random placement of the programmes where policy-makers select the households according to household or regional characteristics (e.g. poor households/ regions), or of self-section where households select themselves depending on their inherent characteristics. The literature regarding program evaluation has addressed these problems through randomization that makes individuals in a treatment group and a comparison group comparable. Rosenbaum and Rubin (1983) introduced matching methods by randomizing the data through a propensity score. A propensity score is a probability that a subject would be assigned to a specific group, and matching subjects on propensity scores produces comparison groups of subjects who would be equally likely to have been assigned

4 In case of yield per hectare, net profit per hectare or technical efficiency, while they are measured in logarithms and thus productivity measures of large farmers are broadly comparable with those of smallholders. However, farm gate prices may be cheaper for large farmers than for smallholders and this may compound the negative relationship between farm size and productivity measures. For instance, Fan et al. (2013) have argued that higher productivity does not translate into higher profits simply because smallholders lack storage and thus are forced to sell at not so remunerative prices at harvest time. As we do not have access to farm gate prices, we cannot consider this effect and our results will have to be interpreted with caution.

5 These regressions are carried out as robustness checks to see whether the *unconditional* relationship between farm size and proxies for agricultural productivity (e.g. yield, intensity of labour use, net profit, technical efficiency) is unchanged once it is controlled for household and other characteristics and we do not impose any theoretical underpinnings (e.g. underlying production or labour supply function) for the specifications.

to the study's group or condition. Thus, propensity score matching provides an estimate of the effect of a "treatment" variable on an outcome variable that is largely free of bias arising from an association between treatment status and observable variables. However, matching methods are not robust against "hidden bias" arising from unobserved variables (such as farmers' motivation, management and production skills) that simultaneously affect assignment to treatment (participation) and the outcome variable (productivity) due to violation of mean conditional independence (see, for example, Cameron and Trivedi, 2005).

3.4 Treatment Effects Model

In this section, we will provide a summary of treatment effects model where the control function approach with endogenous treatment variable accommodates the self-selection of participating farmers. The approach explicitly corrects for the potential bias in the fashion of Heckman's (1979) selection model. Further, randomization is conducted through the selection equation in the control function methods, which is equivalent to that in matching methods using a propensity score (Otsuki, 2011). Our study thus adopts the control function approach because of the need for randomization and the endogenous nature of participation. Specifically, we use treatment-effects model which considers the effect of an endogenously chosen binary treatment on another endogenous continuous variable, conditional on two sets of independent variables. The merit of treatment effects model is that sample selection bias is explicitly estimated by using the results of probit model. However, the weak aspects include (i) strong assumptions are imposed on distributions of the error terms in the first and the second stages, (ii) the results are sensitive to choice of the explanatory variables and instruments, and (iii) valid instruments are rarely found in the non-experimental data and if the instruments are invalid, the results will depend on the distributional assumptions.

The treatment effects model estimates the effect of an endogenous binary treatment, T_i

on a continuous, fully observed outcome variable Y_i, conditional on the independent variables X_i and Z_i. The selection into the treatment T_i is a function of ε_i, which is correlated with v_i, the error term in the equation of the outcome Y_i. The binary decision to obtain the treatment T_i is modelled as the outcome of an unobserved latent variable, T_i^*. It is assumed that T_i^* is a linear function of the exogenous covariates Z_i and a random component ε_i. Specifically,

$$T_i^* = \gamma Z_i' + \varepsilon_i \ , \tag{3}$$

The latent variable is unobservable and its relationship with T_i is specified by

$$T_i = \begin{Bmatrix} 1 & \text{if } T_i^* > 0 \\ 0 & \text{if } T_i^* \leq 0 \end{Bmatrix}. \tag{4}$$

We denote household productivity (technical efficiency) by stochastic frontier analysis as outcome variable and the outcome equation is

$$Y_i = \delta T_i + \beta X_i' + v_i \ , \tag{5}$$

$$(\varepsilon, v) \sim \text{bivariate normal}[0, 0, 1, \sigma_v, \rho].$$

where δ is the average net effect (ANE) of participation in agricultural extension programs. It is not necessarily true to argue that the positive estimate for δ implies that participating in agricultural extension programs increases productivity because, as we will see below, this shows only the net effect without taking account of sample selection term. Here X_i' is a vector of determinants of Y_i.

If unobserved factors in (3) are correlated with v_i of (5), the correlation coefficient between ε_i and v_i (denoted by ρ) is non-zero, and thus, the OLS estimate is inconsistent (Greene, 2008). Then, the expected outcome assuming normal distribution for T becomes

$$E[Y_i | T_i, X_i, Z_i] = X_i^{'}\beta + \delta T_i + E[\nu_i | T_i, X_i, Z_i]$$
$$= X_i^{'}\beta + \delta T_i + \left[\rho_1 \sigma_{v_1} \{\phi(Z_i^{'}\gamma) / \Phi(Z_i^{'}\gamma)\}\right] P(T_i = 1 | X)$$
$$+ \left[\rho_0 \sigma_{v_0} \{-\phi(Z_i^{'}\gamma) / 1 - \Phi(Z_i^{'}\gamma)\}\right] [1 - P(T_i = 1 | X)], \quad (6)$$

where the expected outcome for the participants is

$$E[Y_i | T_i, X_i, Z_i] = X_i^{'}\beta + \delta T_i + \left[\rho_1 \sigma_{v_1} \{\phi(Z_i^{'}\gamma) / \Phi(Z_i^{'}\gamma)\}\right], \quad (7)$$

and the expected outcome for the non-participants is

$$E[Y_i | T_i, X_i, Z_i] = X_i^{'}\beta + \left[\rho_0 \sigma_{v_0} \{-\phi(Z_i^{'}\gamma) / 1 - \Phi(Z_i^{'}\gamma)\}\right]. \quad (8)$$

Here $\rho_1 \sigma_{v_1}$ equals the covariance between ν_i and υ_i for participants, $\rho_0 \sigma_{v_0}$ equals the covariance between ν_0 and υ_0 for non-participants, $\phi(Z_i^{'}\gamma)$ is the marginal probability of standard normal distribution at $Z_i^{'}\gamma$ and $\Phi(Z_i^{'}\gamma)$ is the cumulative distribution function of the standard normal distribution at $Z_i^{'}\gamma$. The third term of (7) and second term of (8) include the inverse Mills ratio to control for possible sample selection bias. The difference in expected outcome between participants and non-participants then becomes

$$E[Y_i | T_i = 1, X_i, Z_i] - E[Y_i | T_i = 0, X_i, Z_i] = \delta + \text{ selection term.} \quad (9)$$

The positive (negative) sign of the selection term implies that OLS overestimates (underestimates) δ and the sign of the selection term depends on that of ρ. The maximum likelihood estimation is utilized because it produces consistent estimators (Maddala, 1983, p.122). Greene (2000, p.180) discusses the standard method of reducing a bivariate normal to a function of a univariate normal and the correlation ρ, which jointly estimates the participation and productivity equations and allows the testing of the significance of cross-equation correlation. The following is the log likelihood for observation *i*,

$$\ln L_i \begin{cases} \ln\Phi\left\{\dfrac{Z_i\gamma+(Y_i-X_i\beta-\delta)\rho/\sigma}{\sqrt{1-\rho^2}}\right\}-\dfrac{1}{2}\left(\dfrac{Y_i-X_i\beta-\delta}{\sigma}\right)^2-\ln\left(\sqrt{2\pi}\sigma\right), & Z_i=1 \\ \ln\Phi\left\{\dfrac{-Z_i\gamma-(Y_i-X_i\beta)\rho/\sigma}{\sqrt{1-\rho^2}}\right\}-\dfrac{1}{2}\left(\dfrac{Y_i-X_i\beta}{\sigma}\right)^2-\ln\left(\sqrt{2\pi}\sigma\right), & Z_i=0 \end{cases} \tag{10}$$

In the maximum likelihood estimation, σ and ρ are not directly estimated. Rather $\ln\sigma$ and atanh ρ are directly estimated, where

$$\text{atanh}\rho=\frac{1}{2}\ln\left(\frac{1+\rho}{1-\rho}\right) \tag{11}$$

The standard error of $\lambda=\rho\sigma$ is approximated through the delta method, which is given by

$$\text{Var}(\lambda)\approx \text{D Var}\left\{(\text{atanh}\rho \quad \ln\sigma)\right\}\text{D}' \tag{12}$$

where D is the Jacobian of λ with respect to atanh ρ and $\ln\sigma$ (Cong and Drukker, 2000). The predicted values of (7) and (8) are derived and compared by the standard *t* test to examine whether the average treatment effect on treated (ATT) or productivity improvement effect is significant. We considered distance from village centre to extension centre as instrument for the participation equation. To construct the distance variable community level raw distances are used. The missing observations without distances are replaced by the values predicted by Tobit estimation.

3.5 Estimation of the impact of agricultural extension on household consumption and vulnerability

We considered mean per capita consumption expenditure (MPCE) as a measure of household present poverty status. We also derived a measure of 'Vulnerability as Expected Poverty' (VEP), an *ex-ante* measure based on Chaudhuri (2003) and Chaudhuri, Jalan and Suryahadi (2002) who applied it to a large cross-section of households in Indonesia and defined vulnerability as the probability that a household will fall into poverty in the future after controlling for the observable household characteristics. It takes the value from 0 to 1 and the higher the value of vulnerability measure, the higher is the probability of a household falling into poverty in the next period. Impact of agricultural extension programs participation on household vulnerability and mean per capita consumption expenditure will also be examined by using the treatment effects model

Deriving Vulnerability Measure

Vulnerability measure as an expected poverty is specified as:

$$\mathrm{VEP}_{it} \equiv \mathrm{V}_{it} = \Pr\left(\mathrm{c}_{i,t+1} \leq \mathrm{z}\right) \tag{13}$$

where vulnerability of household *i* at time *t*, V_{it}, is the probability that the *i-th* household's level of consumption at time *t+1*, $\mathrm{c}_{i,t+1}$, will be below the poverty line, z.

Three limitations, amongst others, should be noted in our measure of vulnerability. First, the present analysis is confined to a consumption (used synonymously with income) threshold of poverty. Second, our measure of vulnerability in terms of the probability of a household's consumption falling below the poverty threshold in the future is subject to the choice of a threshold. Third, while income/consumption volatility underlies vulnerability, the resilience in mitigating welfare losses depends on assets defined broadly-including human, physical and social capital. A household with inadequate physical or financial asset or savings, for example, may find it hard to overcome loss of income. This may translate into lower nutritional intake and rationing out of its members from the labor market (Dasgupta, 1997; Foster, 1995). Lack of physical assets may also impede accumulation of profitable portfolios under risk and generate poverty traps.

The consumption function is estimated by the equation (14).[6]

$$\ln c_i = X_i \lambda + e_i \tag{14}$$

[6] We have used White-Huber sandwich estimator to overcome heteroscedasticity in the sample.

where c_i is mean per capita consumption (MPCE) (i.e. food and non-food consumption expenditure) for the household and X is a vector of observable household characteristics and other determinants of consumption. It is further assumed that the structure of the economy is relatively stable over time and, hence, future consumption stems solely from the uncertainty about the idiosyncratic shocks, e_i. It is also assumed that the variance of the disturbance term depends on:

$$\sigma^2_{e,i} = X_i \theta \qquad (15)$$

The estimates of β and θ are obtained using a three-step feasible generalized least squares (FGLS)[7]. Using the estimates $\hat{\beta}$ and $\hat{\theta}$, we can compute the expected log consumption and the variance of log consumption for each household as follows.

$$E[\ln C_i | X_i] = X_i \hat{\beta} \qquad (16)$$

$$V[\ln C_i | X_i] = X_i \hat{\theta} \qquad (17)$$

By assuming $\ln c_i$ as normally distributed and letting $\Phi(\cdot)$ denote the cumulative density function of the standard normal distribution, the estimated probability that a household will be poor in the future (say, at time $t+1$) is given by:

$$\hat{VEP}_i \equiv \hat{v}_i = \hat{\Pr}(\ln c_i < \ln z | X_i) = \Phi\left(\frac{\ln z - X_i \hat{\beta}}{\sqrt{X_i \hat{\theta}}}\right) \qquad (18)$$

This is an *ex ante* vulnerability measure that can be estimated with cross-sectional data. Note that this expression also yields the probability of a household at time *t* becoming poor at *t+1* given the distribution of consumption at *t*.

A merit of this vulnerability measure is that it can be estimated with cross-sectional

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[7] See Chaudhuri (2003), Chaudhuri et al. (2002), and Hoddinott and Quisumbing (2003) for technical details.

data (Imai 2011; Imai et al., 2011; Imai et al., 2010; Gaiha and Imai, 2009). However, it correctly reflects a household's vulnerability only if the distribution of consumption across households, given the household characteristics at time t, represents time-series variation of household consumption. Hence this measure requires a large sample in which some households experience positive shocks while others suffer from negative shocks. Also, the measure is unlikely to reflect unexpected large negative shocks (e.g., Asian financial crisis), if we use the cross-section data for a normal year.

4. Results

4.1 Agricultural Productivity Estimation

Table 1 presents the results of household crop productivity estimated by stochastic frontier (SF) models with two specifications, that is, Cobb-Douglas without homogeneity conditions imposed on the parameter (or without 'constant returns to scale (CRS)' constraints) (Column 1) and Cobb-Douglas with CRS constraints (Column 2). Both models show that land and labour are primary inputs, with coefficient estimates (or elasticity estimates) ranged from 0.34 to 0.36 for land, 0.45 to 0.50 for labour and 0.14 to 0.15 for other inputs.[8]

Table 1: Results of stochastic frontier analysis

	Cobb-Douglas(TI)		Cobb-Douglas - CRS(TI)		Cobb-Douglas - CRS(TVD)	
Variables	Coeff	SE	Coeff	SE	Coeff	SE
Constant	7.9746	118.9354	7.5055	79.4471	5.6771***	0.5001
lnLand	0.3407***	0.0188	0.358***	0.0177	0.3571***	0.0177
lnLabor	0.4508***	0.0236	0.4909***	0.0185	0.4981***	0.0185
lnInput	0.1446***	0.0115	0.1512***	0.0112	0.1448***	0.0112
Sigma2	1.112	0.0256	1.1056	0.0251	1.083	0.0251
Gamma	0.4193	0.0176	0.407	0.0171	0.4077	0.0174
Sigma_u2	0.4663	0.0262	0.45	0.0251	0.4415	0.0252
Sigma_v2	0.6457	0.0183	0.6556	0.0183	0.6415	0.0179
lnSigma2	0.1062***	0.023	0.1004	0.0227	0.0797	0.0232

8 In CRS specification in the second and third columns, sum of coefficient estimates of ln Land, ln Labour and ln Input is constrained to be 1, while no restrictions are imposed in the first column. The coefficient estimates are similar as only a difference between these cases comes from restrictions to coefficient estimates imposed on the CRS specification.

ilgtGamma	-0.3256***	0.0721	-0.3763***	0.0709	-0.3736***	0.072
mu	4.9911	118.9353	4.8333	79.447	2.9109***	0.495
eta					0.0319***	0.0079
Statistics						
No. of obs.	4785		4785		4785	
No. of groups	2247		2247		2247	
Wald chi2	1633.38***		5703.45***		1342.65***	

TI is time-invariant model, TVD is time-varying decay model; The likelihood estimation don't converge in time-varying decay estimation for unconstraint model, so we skipped the time-invariant estimation for unconstraint model.
Note: The symbol *** indicate 1% significance level.

Table 2 presents the descriptive statistics of technical efficiencies (TE) estimated from the SF models. The descriptive statistics of technical efficiency are defined by the equation (2) for each model. It is noted that technical efficiency indicates how the observed output is compared with the maximum output which could be achieved if all the available inputs were used most efficiently. The results indicate that household level crop productivity, or TE is only around 6 to 7 percent, which is generally very low. Hence, there is further prospect for household crop productivity improvement in Uganda. The level of technical efficiency is surprisingly similar between these models.

Table 2: Descriptive statistics of technical efficiency of different models

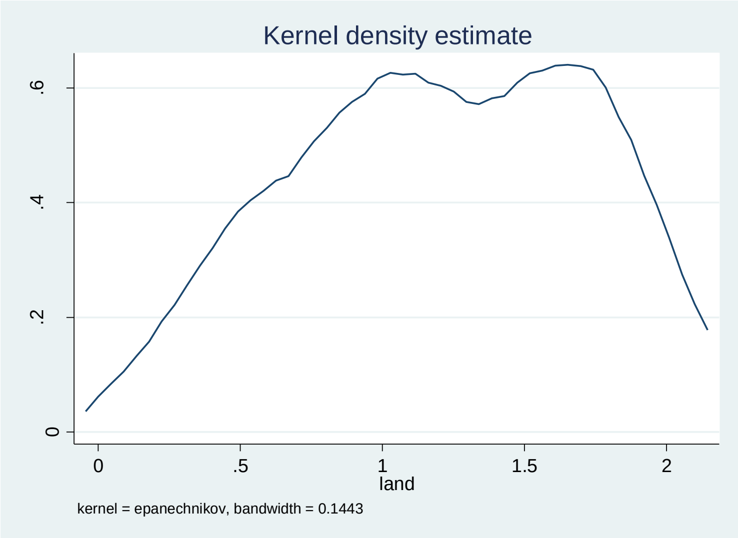
Models	Obs	Mean	Std. Dev.	Min	Max
Cobb-Douglas – TI	8578	0.0701	0.0819	0.0009	0.2225
Cobb-Douglas –CRS – TI	8578	0.0716	0.0809	0.0010	0.2217
Cobb-Douglas –CRS - TVD	4785	0.0653	0.0424	0.0024	0.7696

4.2 Relationship between Farm Size and Agricultural Productivity Estimation

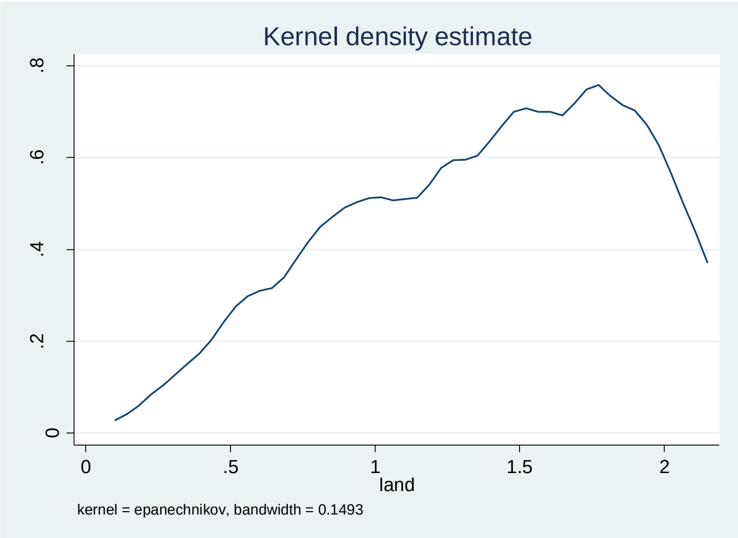
This subsection presents the results on the relationship between farm size and agricultural productivity. Figure 1 shows the kernel estimate for the distribution of households with respect to land size in rural Uganda in 2009, 2010 and 2011, which looks similar to that of rural Rwanda. In both countries the relationship is represented by the bell-shaped distribution with dense contribution at the left tail end. However, mean is much higher in Uganda (1 to 1.5 hectare) than in Rwanda (0.37 hectare). The distribution implies that the share of smallholders is higher than that of large holders.

Figure 1. Distribution of Cultivated Land Area per household (ha)

2009



2010



2011

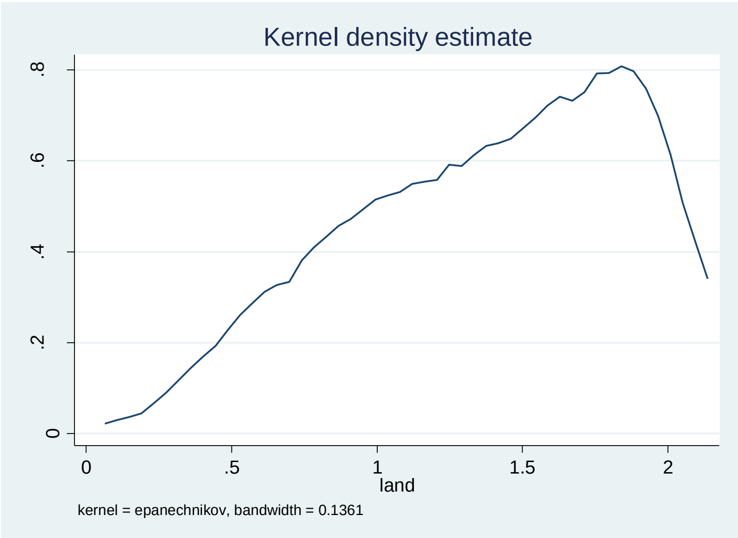
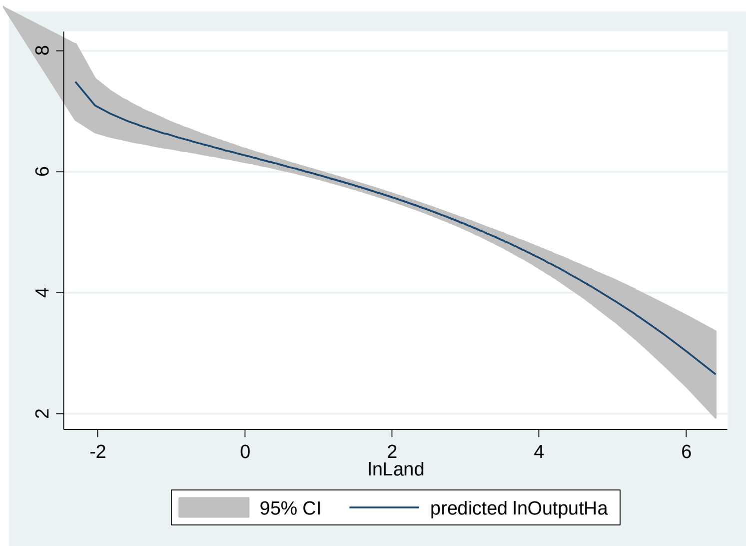


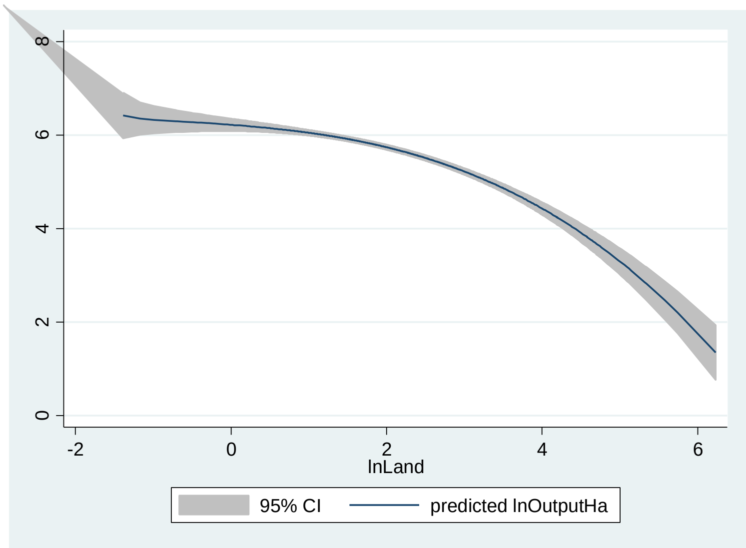
Figure 2 shows the relationship between farm size (cultivated land area per household) and yield (output per hectare). As in the case of Rwanda (Ali and Deninger, 2013), we observe the negative relation between farm size and yield in 2009, 2010 and 2011, which is consistent with the literature. The results are broadly consistent with Ali and Deninger (2013).

Figure 2. Farm Size (Cultivated Land Area per household (ha)) and Yield (output per hectare)

2009



2010



2011

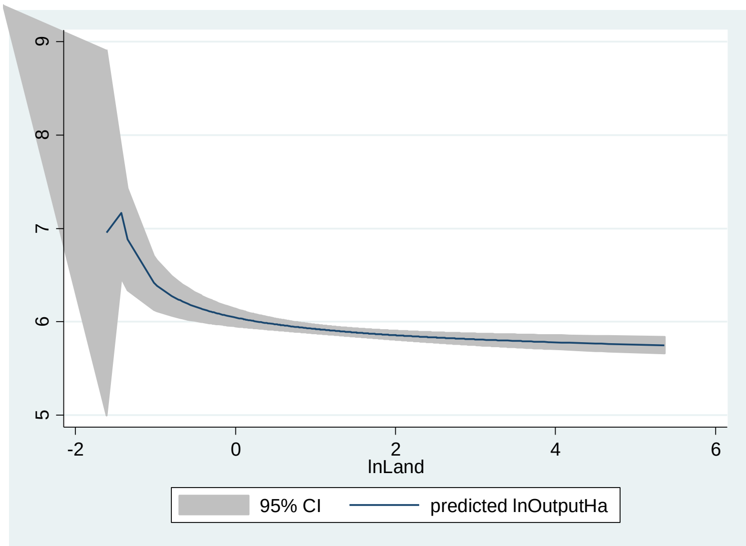
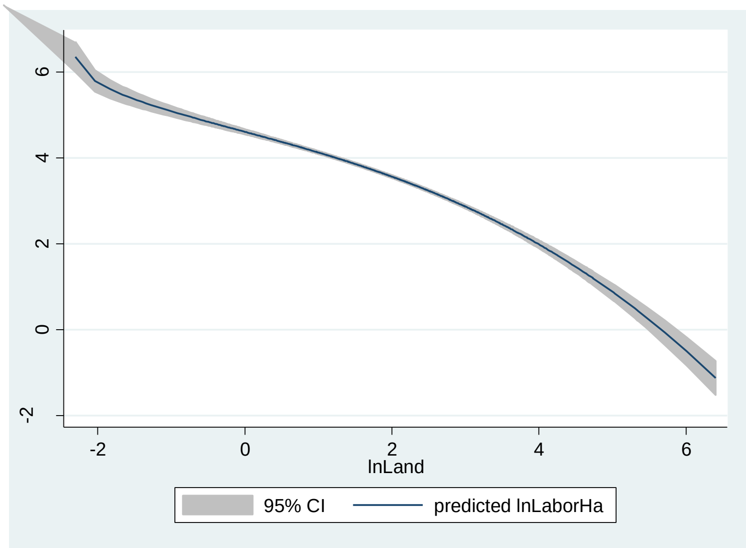
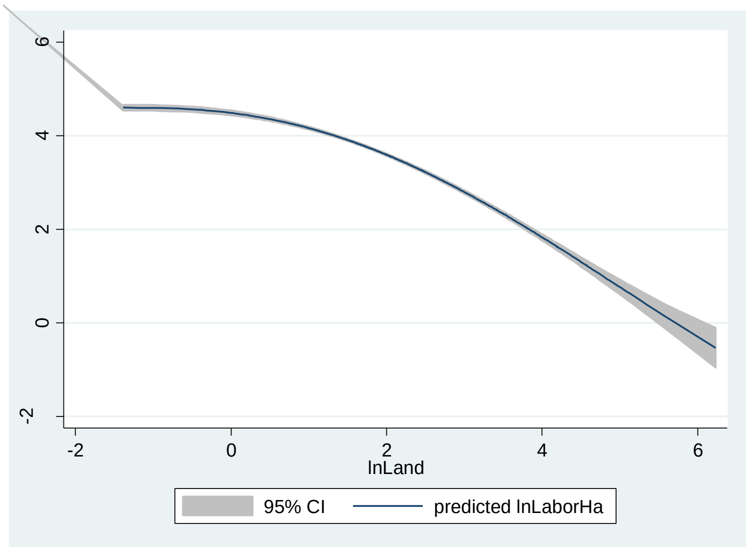


Figure 3 shows the relationship between farm Size and intensity of labour use. It has been suggested that intensity of labour use tends to decline as the farm size increases (Assuncao and Braido 2007; Ali and Deninger, 2013), leading to higher agricultural productivity of farming households with smaller cultivated areas.

Figure 3. Farm Size (Cultivated Land Area per household (ha)) and Intensity of Labour Use 2009


-2
0
2
4
6
lnLand
95% CI
predicted lnLaborHa

2010


-2
0
2
4
6
lnLand
95% CI
predicted lnLaborHa

2011

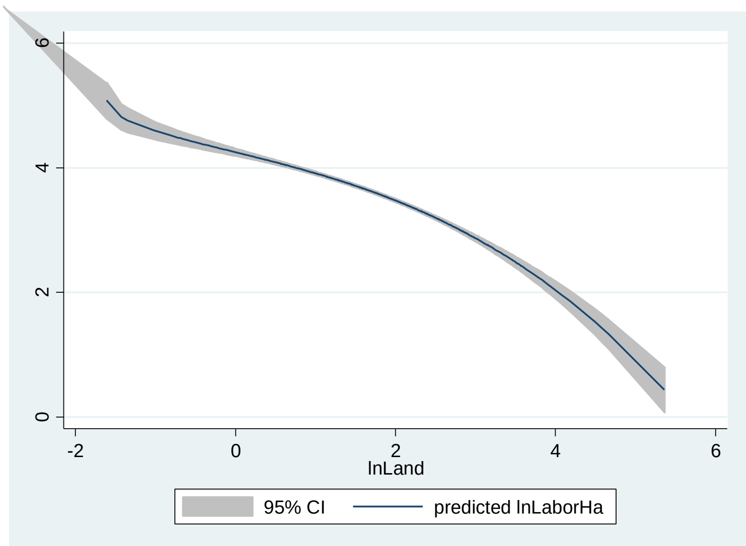
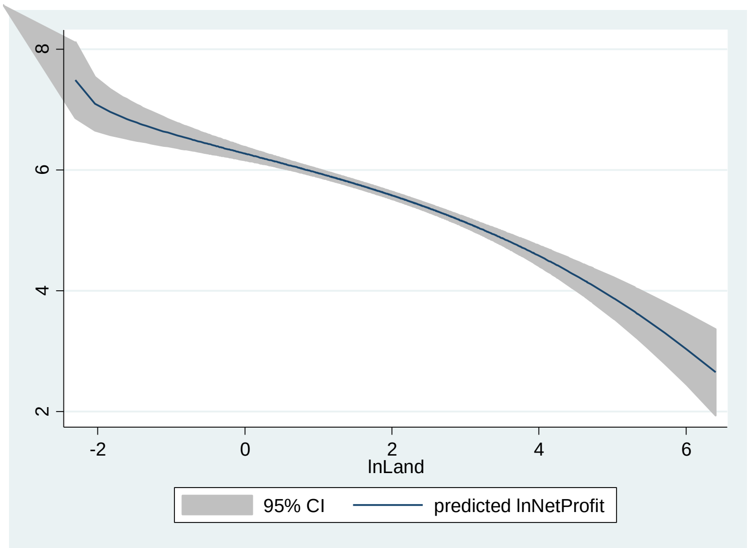

0
2
4
6
-2
lnLand
95% CI
predicted lnLaborHa

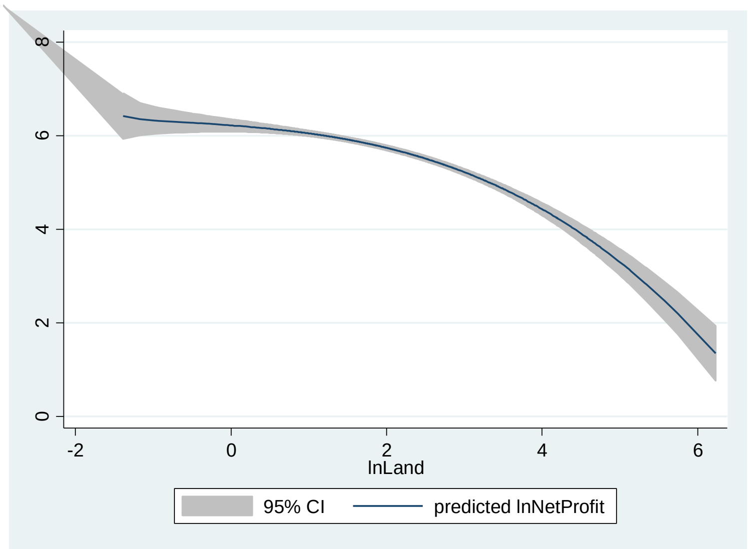
Figure 4 presents graphically the relationship between farm size and net profit. There is observed a clear negative relationship between farm size and net profit particularly in 2009 and 2010. A negative relation is observed mainly for smallholders in 2011. The result is in sharp contrast with Ali and Deninger's (2013) result for Rwanda where net profit is virtually constant for all holding sizes.

Figure 4. Farm Size (Cultivated Land Area per household (ha)) and Net Profit

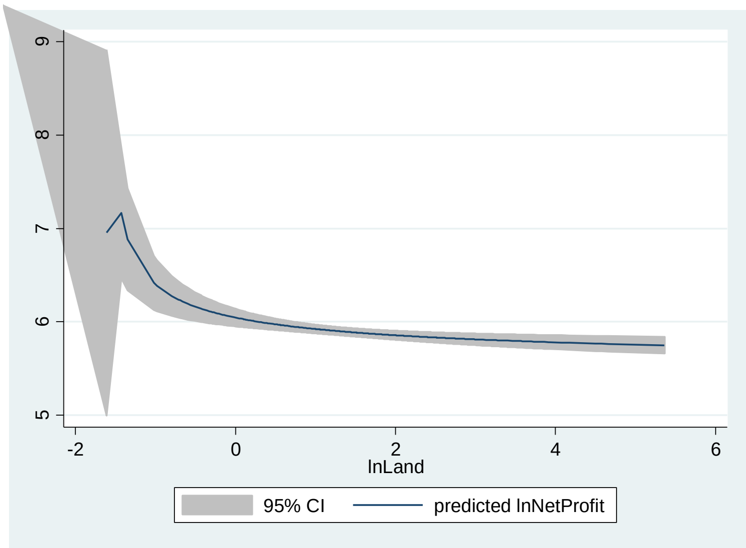
2009



2010



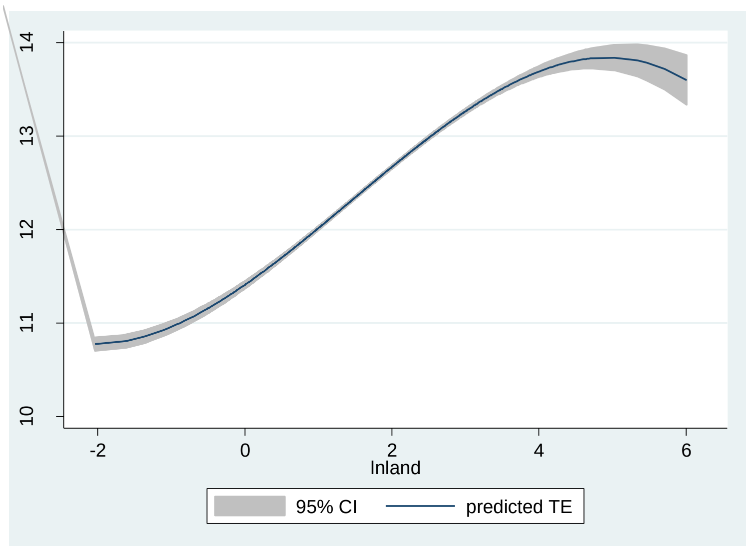
2011



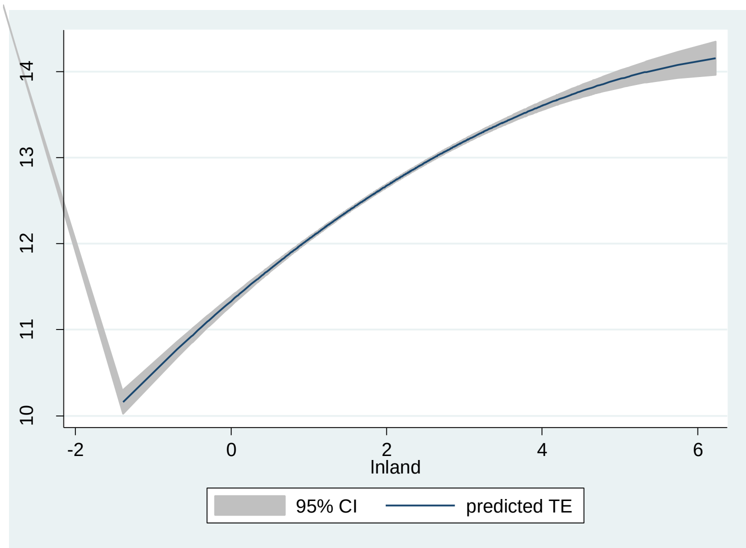
In Figure 5, we find a positive relationship for three rounds, 2009, 2010, and 2011 between farm size and technical efficiency (TE) estimated in the last subsection. This may be due to the fact that holders will benefit from economy of scale in agricultural production. The results are broadly same for three rounds.

Figure 5. Farm Size (Cultivated Land Area per household (ha)) and Technical Efficiency (based on Cobb-Douglas specification without restriction)

2009



2010



2011

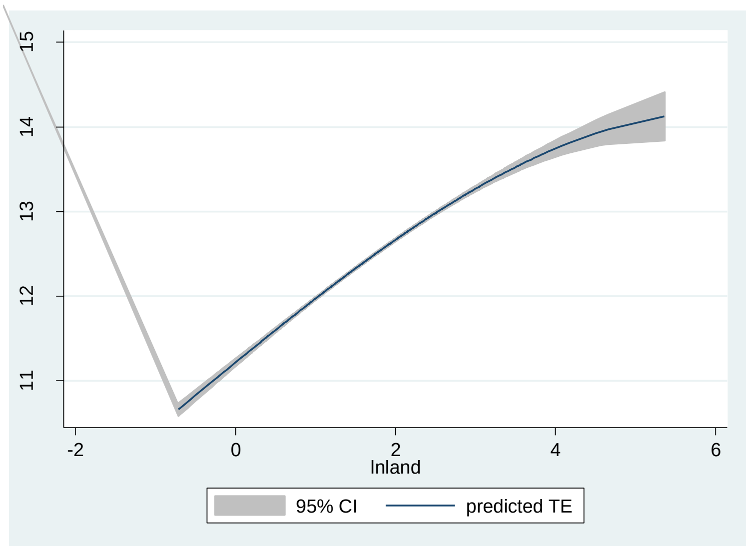


Table 3 indicates conditional relationships between farm size and various proxies for agricultural productivity, namely, yield, intensity of labour use, and technical efficiency. We estimated each proxy for agricultural productivity by log cultivated land area as well as various household characteristics and regional dummies. Both fixed effects (FE) model and random effects (RE) model have been estimated. It is found that in Cases (1) to (4), we find a clear negative and statistical association between farm size and agricultural productivity – proxied by yield or intensity of labour use. Because all the variables are in logarithm, the coefficient estimates show the elasticity estimates. That is, a 1 % increase in cultivated land area is associated with 0.53% to 0.74% decrease in yield, or 0.69% to 0.82% decrease in the labour use, other factors being equal. This appears to be a substantial effect of size of farming on productivity. In Columns (5) and (6), the results on TE are shown. Contrary to Ali and Deninger (2013) we do not find a positive and statistically significant relation between farm size and TE.

Table 3: Conditional relationships between farm size and agricultural productivity

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
	FE	RE	FE	RE	FE	RE
VARIABLES	lnYield	lnYield	lnLABOUR	lnLABOUR	Technical_Efficiency1	Technical_Efficiency1
log Cultivated Land Area (ha)	-0.737***	-0.526***	-0.815***	-0.691***	0.451***	0.531***
	(0.0203)	(0.0153)	(0.0133)	(0.00894)	(0.00910)	(0.00606)
Head age	-0.00872	0.00925	0.0237*	0.0193***	0.0165**	0.00863***
	(0.0190)	(0.00674)	(0.0126)	(0.00363)	(0.00816)	(0.00248)
Head age square	8.43e-05	-9.69e-05	-0.000179	-0.000178***	-0.000145**	-8.64e-05***
	(0.000175)	(6.46e-05)	(0.000116)	(3.48e-05)	(7.33e-05)	(2.39e-05)
Head education	-0.0188	0.0157	-0.00313	0.0155**	-0.00906	0.00295
	(0.0187)	(0.0118)	(0.0123)	(0.00666)	(0.00804)	(0.00444)
Head education square	0.00153	0.000363	0.00104	-0.000539	0.00119*	0.000246
	(0.00154)	(0.000950)	(0.00102)	(0.000532)	(0.000651)	(0.000352)
Household size	0.0517***	0.0632***	0.0200***	0.0391***	0.0119**	0.0262***
	(0.0112)	(0.00541)	(0.00732)	(0.00295)	(0.00489)	(0.00201)
Head sex	0.117	0.188***	0.000858	0.0261	0.000665	0.0576***
	(0.102)	(0.0416)	(0.0666)	(0.0224)	(0.0438)	(0.0152)
Rural	-0.202	0.210***	0.0766	0.285***	-0.0123	0.121***
	(0.138)	(0.0523)	(0.0925)	(0.0284)	(0.0568)	(0.0189)
burden_share_female	-0.267	-0.338***	-0.108	-0.0920	-0.0596	-0.0750*
	(0.193)	(0.115)	(0.126)	(0.0638)	(0.0887)	(0.0441)
Female share	0.517**	0.274**	0.0679	0.0365	0.0325	0.0134
	(0.213)	(0.113)	(0.140)	(0.0624)	(0.0968)	(0.0430)
Region-Central Kampala	0.0221	0.0930	0.172	0.178	0.211	0.165*
	(0.456)	(0.262)	(0.301)	(0.148)	(0.187)	(0.0994)
Region-East	0.394	-0.243	0.133	0.119		0.0882
	(1.148)	(0.263)	(0.759)	(0.148)		(0.0996)
2010.year	0.0964***	0.0865***	-0.00109	-0.0117	-0.00774	-0.0174
	(0.0280)	(0.0269)	(0.0184)	(0.0174)	(0.0120)	(0.0109)
2011.year	0.118***	0.154***	-0.184***	-0.158***	-0.0667***	-0.0498***
	(0.0291)	(0.0269)	(0.0192)	(0.0174)	(0.0124)	(0.0108)
Region-North		-0.322		0.0154		0.0673
		(0.263)		(0.148)		(0.0995)

Region-Kampala		0.612**		0.172		0.173*
		(0.263)		(0.148)		(0.0994)
Constant	6.633***	5.446***	4.101***	3.693***	11.18***	10.91***
	(0.609)	(0.312)	(0.404)	(0.173)	(0.232)	(0.117)
Observations	5,847	5,847	5,897	5,897	4,739	4,739
R-squared	0.295		0.520		0.521	
Number of HHID	2,357	2,357	2,364	2,364	2,220	2,220

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

4.3 Impact of participation in agricultural extension programmes on crop productivity, consumption and vulnerability

This subsection summarises the results of treatment effects model which has been applied to estimate the effects of participation in agricultural extension programs. We have used the estimates of technical efficiency derived by Cobb-Douglas model without CRS as a measure of productivity because this model is simpler than that with CRS. We also considered (i) mean per capita consumption expenditure (MPCE) as a proxy for household poverty as well as (ii) vulnerability derived as expected poverty. We present the results of extension program participation impact on productivity in Table 4, those on log MPCE in Table 5 and those on vulnerability in Table 6 respectively. Table 7 summarises the average treatment effect on treated (ATT) derived by treatment effects model (the results of which are shown in Tables 4, 5 and 6) as well as whether extension program improves productivity and log MPCE and reduces vulnerability.

In Tables 4, 5 and 6, six different types of agricultural extension services have been considered for impact estimation, namely, (i) NAADS (Government), (ii) NGO, (iii) Cooperatives, (iv) large farmers, (v) input suppliers and (vi) other types of extension. Treatment effects model is applied for these six cases separately. The NAADS extension services are government extension services provided under the new extension approach introduced in 2001, while the NGO extension services are provided by non-government organizations.

The results of participation equations based on probit model are shown in the second panel of Tables 4, 5 and 6. Our instrument for the participation equation, the distance to extension service centre - shown in bold in these tables - is negative and significant for NAADS, NGO extension programme participation (except Table 6 - vulnerability model), while statistically insignificant for cooperatives extension program participation. This is expected as a longer distance to the formal extension service centre deters the NAADS and NGO programme participation, validating our specification. The distance is not significant for other types of extension services, implying that the availability of extension service centre mainly influences the participation in government and non-government extension programmes, but not others.[9] This implies that farmers tend to seek different providers if the village is located far away from the extension service centre. The distance to extension services is unlikely to have a direct effect on agricultural productivity, expenditure or vulnerability, which is supported by relatively low coefficient of correlation between the instrument and outcome variables (see Appendix 2).[10]

[9] If the distance is not statistically significant in the first stage, however, the instrument is deemed weak and thus the second stage result on the impact of extension programmes will have to rely on the distributional assumption made for treatment effects model. Therefore, the results in a few cases will have to be interpreted with caution. We have found that use of different instruments - which were found to perform more poorly than the distance – in different cases according to their statistical significance will make comparisons of different cases difficult. We have thus decided to use the distance from extension service centres as an instrument, realising the aforementioned limitations of our approach.

[10] However, when distance variable is not statistically significant, the final results of impact estimation should be interpreted with caution as they are dependent on the distributional assumptions for the treatment effects model.

Table 4 The Results of Treatment Effects Model on the Effects of Agricultural Extension Programs Participation on Household Agricultural Crop Productivity in Uganda

Variables	(i) NAADS (Government)		(ii)NGO		(iii)Cooperatives		(iv)Input supplier		(v)Large farmer		(vi)Others	
Impact equation	Coef.	Z value	Coef.	Z value	Coef.	Z value	Coef.	Z value	Coef.	Z value	Coef.	Z value
Year 2010 (dummy)	0.0079***	3.2	-0.0068***	-2.71	-0.0071***	-2.78	-0.0064***	-2.64	-0.0069***	-2.87	-.0063**	-2.51
Year 2011 (dummy)	0.0044	1.49	-0.0073**	-2.39	-0.0072**	-2.48	-0.0070**	-2.41	-0.0077**	-2.56	-.0072**	-2.48
Head age	-0.0023***	-4.91	-0.0003	-0.77	-0.0003	-0.81	-0.0003	-0.78	-0.0003	-0.72	-0.0003	-0.63
Head age square	0.0001***	3.69	4.39E-06	1.14	4.57E-06	1.17	4.59E-06	1.18	4.22E-06	1.08	3.88E-06	0.98
Head education	-0.0054***	-5.68	0.0007	0.86	0.0008	1.02	0.0007	0.97	0.0008	1.08	0.0007	0.89
Head education square	0.0004***	6.08	-0.0001	-0.91	-0.0001	-1.05	-0.0001	-1.02	-0.0001	-1.1	-0.0001	-0.78
Household size	-0.0032***	-7.82	-0.0009***	-2.81	-0.0009***	-2.86	-0.0009***	-3.07	-0.0009***	-2.79	-.0009***	-2.92
Head sex	-0.0047*	-1.76	-0.0033	-1.38	-0.0036	-1.47	-0.0036	-1.51	-0.0031	-1.29	-0.0037	-1.51
Rural (dummy)	-0.0651***	-18.8	-0.0066**	-2.16	-0.0067**	-2.26	-0.0069**	-2.31	-0.0066**	-2.24	-.0060**	-1.98
Female share	0.0045	0.64	0.0074	1.03	0.0077	1.13	0.0081	1.17	0.0078	1.13	0.0075	1.09
Female burden share	-0.0248***	-3.2	0.0031	0.39	0.0028	0.38	0.0015	0.2	0.0028	0.38	0.0031	0.42
Household head tribe	0.0001*	1.73	-0.0001	-0.23	-0.0001	-0.22	-0.0001	-0.43	-2.34E-05	-0.35	-8.11E-06	-0.12
Household training (dummy)	-0.0005	-0.13	0.0013	0.31	0.0017	0.47	0.0009	0.27	0.0008	0.22	0.0016	0.44
Central Kampala (dummy)	-0.0811***	-14	-0.0289**	-2.04	-0.0280**	-2.05	-0.0247*	-1.73	-0.0269**	-1.96	-0.0272**	-1.99
East region (dummy)	-0.1097***	-15.4	-0.0433***	-3.07	-0.0431***	-3.15	-0.0407***	-2.89	-0.0427***	-3.12	-0.0430***	-3.15
North region (dummy)	-0.0974***	-16	-0.0291**	-2.14	-0.0289**	-2.13	-0.0262*	-1.86	-0.0289**	-2.12	-0.0289**	-2.14
Kampala (dummy)	-0.0590***	-10.9	-0.0280**	-2.04	-0.0283**	-2.08	-0.0256*	-1.85	-0.0268*	-1.96	-0.0268**	-1.97
Extension	0.0641***	3.12	0.0017	0.07	0.0125	0.44	0.0216	0.72	-0.0358	-0.67	-0.0250	-0.63
Constant	0.2796***	19.28	0.0745***	4.38	0.0751***	4.4	0.0721***	4.18	0.0736***	4.32	0.0725***	4.22
Participation equation												
Extension distance	**-0.0001*****	**-3.81**	**-0.0002****	**-2.25**	**9.42E-06**	**0.84**	**-9.46E-06**	**-0.67**	**-0.0003**	**-1.36**	**-0.0001**	**-0.81**
Year 2010 (dummy)	-0.1911***	-3.71	0.1951*	1.71	0.3082**	2.16	-0.2802	-1.39	-0.2009	-0.87	0.2664*	1.65
Year 2011 (dummy)	-0.2490***	-4.2	0.2298*	1.7	-0.0013	-0.01	-0.1313	-0.58	-3.9869	-0.01	-0.0295	-0.11
Head age	0.0512***	4.9	-0.0055	-0.24	0.0279	0.91	0.0536	1.16	0.0131	0.34	0.0418	1.16
Head age square	-0.0004***	-4.12	-0.0001	-0.06	-0.0003	-1.01	-0.0008	-1.53	-0.0001	-0.34	-0.0004	-1.18
Head education	0.1009***	5.22	0.1165***	2.71	-0.0374	-0.72	0.0455	0.64	0.0671	0.89	-0.0312	-0.55
Head education square	-0.0049***	-3.47	-0.0077**	-2.44	0.0029	0.77	-0.0022	-0.44	-0.0059	-0.97	0.0057	1.44
Household size	0.04855***	6.43	0.0411***	2.61	0.0622***	3.4	0.0218	0.84	0.0279	1.11	0.0125	0.57
Head sex	0.0718	1.21	-0.0758	-0.61	0.4593**	2.26	0.2865	1.27	0.1906	0.81	-0.2129	-1.24
Rural (dummy)	0.3839***	5.8	0.2797*	1.73	0.3336	1.34	0.3423	1.16	-0.0296	-0.11	0.4104	1.53
Female share	0.2021	1.22	0.6478*	1.81	-0.5356	-0.94	-0.7448	-1.11	0.1729	0.25	0.1254	0.23
Female burden share	-0.0726	-0.4	-0.8655**	-2.22	0.3691	0.61	1.3829*	1.95	-0.0680	-0.1	-0.0644	-0.12
Household head tribe	-0.0016	-0.98	-0.0024	-0.72	-0.0007	-0.15	0.0124**	2.07	-0.0060	-0.92	0.0080	1.44
Household training (dummy)	0.1115	1.3	0.4721***	3	-0.3066	-1.12	0.3360	1.4	-4.0063	-0.01	0.0337	0.14
Central Kampala (dummy)	4.4507	0.03	3.4263	0.02	3.0064	0.02	-2.0927***	-2.76	3.8177	0	2.7931	0.03
East region (dummy)	4.9744	0.04	3.9111	0.03	2.7874	0.01	-1.4487*	-1.92	3.3925	0	2.3258	0.02
North region (dummy)	4.6591	0.04	3.2288	0.02	2.5596	0.01	-1.6861**	-2.3	3.3463	0	2.3845	0.02
Kampala (dummy)	4.1604	0.03	3.5899	0.02	3.1858	0.02	-1.1052	-1.53	3.9248	0	3.0638	0.03
Constant	-7.8751	-0.06	-5.6292	-0.04	-6.2803	-0.03	-2.4862*	-1.94	-6.3028	0	-6.3791	-0.06
N	5057		1779		1779		1779		1779		1779	
chi2	2077.75***		183.39***		171.44***		169.22***		138.92***		157.34***	
Lambda	-0.0522***	-4.52	-0.0021	-0.16	-0.0100	-0.76	-0.0091	-0.66	0.0138	0.61	0.0079	0.45
Rho	-0.7208		-0.0556		-0.2692		-0.2454		0.3711		0.2119	
Sigma	0.0725		0.0370		0.0372		0.0371		0.0372		0.0370	

Note: The symbols *, ** and *** indicate 10%, 5% and 1% significance levels, respectively.

Table 5 The Results of Treatment Effects Model on the Effects of Agricultural Extension Programs Participation on log MPCE in Uganda

Variables	(i) NAADS (Government)		(ii)NGO		(iii)Cooperatives		(iv)Input supplier		(v)Large farmer		(vi)Others	
Impact equation	Coef.	Z value	Coef.	Z value	Coef.	Z value	Coef.	Z value	Coef.	Z value	Coef.	Z value
Year 2010 (dummy)	-0.0255	-1.19	0.1195***	3.15	0.1031***	2.67	0.0941**	2.44	0.1170***	3.19	0.1153***	3.05
Year 2011 (dummy)	0.1010***	3.99	0.1158**	2.5	0.1032**	2.37	0.0943**	2.04	0.1210***	2.67	0.1035**	2.36
Head age	-0.0079**	-1.97	0.0010	0.16	0.0012	0.2	0.0016	0.24	0.0008	0.13	0.0021	0.33
Head age square	0.0001**	2.25	0.0001	0.42	0.0001	0.43	0.0001	0.2	0.0001	0.48	0.0001	0.27
Head education	-0.0183**	-2.24	0.0118	0.93	0.0073	0.65	0.0078	0.65	0.0044	0.38	0.0062	0.54
Head education square	0.0047***	8.48	0.0024**	2.57	0.0027***	3.14	0.0028***	3.04	0.0029***	3.36	0.0029***	3.18
Household size	-0.0526***	-14.97	-0.0339***	-6.8	-0.0370***	-7.17	-0.0346***	-7.19	-0.0372***	-7.97	-0.0355***	-7.74
Head sex	0.0348	1.54	-0.0173	-0.47	-0.0183	-0.49	0.0036	0.09	-0.0202	-0.55	-0.0166	-0.45
Rural (dummy)	-0.4217***	-15.07	-0.3136***	-6.8	-0.3280***	-7.37	-0.3055***	-6.5	-0.3220***	-7.24	-0.3190***	-6.99
Female share	0.2190***	3.72	0.3391***	3.08	0.3134***	3.02	0.2786**	2.53	0.3006***	2.87	0.3090***	2.97
Female burden share	-0.8542***	-13	-0.8415***	-7.08	-0.8066***	-7.32	-0.7320***	-6.13	-0.8030***	-7.2	-0.8028***	-7.23
Household head tribe	0.0014**	2.12	0.0022**	2.2	0.0023**	2.32	0.0030***	2.79	0.0025**	2.51	0.0023**	2.33
Household training (dummy)	0.1285***	3.83	0.1117*	1.76	0.0878	1.61	0.1062*	1.84	0.1030*	1.84	0.0842	1.55
Central Kampala (dummy)	-0.6788***	-13.61	-0.5297**	-2.53	-0.5609***	-2.75	-0.7168***	-3.22	-0.5854***	-2.83	-0.5498***	-2.68
East region (dummy)	-0.7852***	-12.62	-0.6293***	-2.93	-0.6791***	-3.32	-0.8040***	-3.64	-0.6911***	-3.34	-0.6783***	-3.3
North region (dummy)	-0.6460***	-12.27	-0.4642**	-2.24	-0.4801**	-2.37	-0.6289***	-2.85	-0.4889**	-2.38	-0.4820**	-2.36
Kampala (dummy)	-0.2125***	-4.62	-0.2024	-0.96	-0.2442	-1.2	-0.3482	-1.59	-0.2707	-1.31	-0.2243	-1.09
Extension	0.5086***	2.7	-0.3406	-0.91	0.2215	0.51	-1.1200***	-3.08	1.1934	1.6	-0.2680	-0.46
Constant	11.9990***	94.65	11.3625***	43.74	11.4044***	44.71	11.5093***	42.29	11.4170***	44.36	11.3709***	43.89
Participation equation												
Extension distance	**-0.0001*** **	**-3.76**	**-0.0001** **	**-2.22**	**0.0001**	**0.83**	**0.0001**	**-0.67**	**0.0001**	**-1.37**	**0.0001**	**-0.82**
Year 2010 (dummy)	-0.1954***	-3.78	0.1820	1.58	0.3138**	2.19	-0.2779	-1.37	-0.1892	-0.82	0.2719*	1.68
Year 2011 (dummy)	-0.2459***	-4.14	0.2307*	1.7	-0.0014	-0.01	-0.1312	-0.58	-3.9889	-0.01	-0.0294	-0.11
Head age	0.0511***	4.87	-0.0059	-0.26	0.0282	0.92	0.0536	1.16	0.0136	0.36	0.0419	1.16
Head age square	-0.0004***	-4.12	0.0001	-0.03	-0.0003	-1.02	-0.0008	-1.53	-0.0001	-0.35	-0.0004	-1.18
Head education	0.0964***	4.97	0.1166***	2.71	-0.0361	-0.7	0.0457	0.65	0.0685	0.91	-0.0301	-0.53
Head education square	-0.0046***	-3.22	-0.0077**	-2.44	0.0029	0.74	-0.0022	-0.44	-0.0061	-0.99	0.0056	1.41
Household size	0.0484***	6.39	0.0420***	2.66	0.0620***	3.39	0.0218	0.83	0.0276	1.1	0.0124	0.57
Head sex	0.0748	1.25	-0.0776	-0.63	0.4609**	2.27	0.2868	1.27	0.1930	0.82	-0.2127	-1.24
Rural (dummy)	0.3956***	5.94	0.2692*	1.66	0.3179	1.27	0.3402	1.15	-0.0430	-0.15	0.4026	1.49
Female share	0.1832	1.1	0.6822*	1.9	-0.5322	-0.93	-0.7449	-1.11	0.1761	0.26	0.1317	0.24
Female burden share	-0.0515	-0.28	-0.8835**	-2.26	0.3631	0.6	1.3818*	1.95	-0.0750	-0.11	-0.0710	-0.13
Household head tribe	-0.0016	-0.95	-0.0023	-0.71	-0.0007	-0.16	0.0124**	2.07	-0.0061	-0.92	0.0080	1.43
Household training (dummy)	0.1127	1.32	0.4757***	3.02	-0.3072	-1.12	0.3354	1.4	-4.0099	-0.01	0.0323	0.14
Central Kampala (dummy)	4.443	0.03	3.4457	0.02	3.0162	0.02	-2.0911***	-2.76	3.8272	0.01	2.7965	0.03
East region (dummy)	4.965	0.04	3.9315	0.03	2.797	0.01	-1.4474*	-1.92	3.4009	0.01	2.3297	0.02
North region (dummy)	4.6535	0.04	3.2269	0.02	2.5718	0.01	-1.6840**	-2.29	3.3576	0.01	2.3925	0.02
Kampala (dummy)	4.1445	0.03	3.6117	0.02	3.1995	0.02	-1.1035	-1.53	3.9381	0.01	3.0690	0.03
Constant	-7.8565	-0.06	-5.6543	-0.04	-6.286	-0.03	-2.4862*	-1.94	-6.3178	0.01	-6.3838	-0.06
N	5028		1774		1774		1774		1774		1774	
chi2	3401.613		604.228		610.2623		552.8005		566.3025		587.6879	
Lambda	-0.2391**	-2.26	0.1987	1.04	-0.0554	-0.28	0.5789***	3.53	-0.3421	-1.09	0.2068	0.81

Rho	-0.3898	0.3521	-0.0999	0.9821	-0.6088	0.37
Sigma	0.6135	0.5642	0.5550	0.5894	0.5619	0.5588

Note: The symbols *, ** and *** indicate 10%, 5% and 1% significance levels, respectively.

Table 6 The Results of Treatment Effects Model on the Effects of Agricultural Extension Programs Participation on Vulnerability in Uganda

Variables	(i) NAADS (Government)		(ii)NGO		(iii)Cooperatives		(iv)Input supplier		(v)Large farmer		(vi)Others	
Impact equation	Coef.	Z value	Coef.	Z value	Coef.	Z value	Coef.	Z value	Coef.	Z value	Coef.	Z value
Year 2010 (dummy)	0.0001*	1.92	0.0001	-0.21	0.0001	-	0.0001	0.23	0.0001	-	0.0001	-0.29
Year 2011 (dummy)	-0.0001***	-13	-0.0001***	-6.5	0.0001	-	-0.0001***	-7.15	0.0001	-	-0.0001***	-6.19
Head age	-0.0001***	-14.82	-0.0001***	-8.14	0.0001	-	-0.0001***	-8.58	0.0001	-	-0.0001***	-7.52
Head age square	0.0001***	16.38	0.0001***	9.63	0.0001	-	0.0001***	10.13	0.0001	-	0.0001***	8.8
Head education	-0.0001**	-2.06	0.0001	0.89	0.0001	-	0.0001	0.92	0.0001	-	0.0001	1.19
Head education square	-0.0001***	-6.46	-0.0001***	-6.33	0.0001	-	-0.0001***	-6.83	0.0001	-	-0.0001***	-6.48
Household size	0.0001***	9.55	0.0001***	10.28	0.0001	-	0.0001***	11.34	0.0001	-	0.0001***	9.47
Head sex	-0.0001**	-2.39	0.0001	-1.03	0.0001	-	0.0001	-0.84	0.0001	-	0.0001	0.43
Rural (dummy)	0.0001***	11.23	0.0001***	10.85	0.0001	-	0.0001***	11.66	0.0001	-	0.0001***	9.16
Female share	-0.0001***	-16.44	-0.0001***	-7.57	-0.0001	-	-0.0001***	-7.9	-0.0001	-	-0.0001***	-6.81
Female burden share	0.0002***	20.7	0.0002***	13.82	0.0002	-	0.0002***	14.63	0.0002	-	0.0002***	11.92
Household head tribe	-0.0001***	-2.99	-0.0001***	-6.4	0.0001	-	-0.0001***	-6.58	0.0001	-	-0.0001***	-6.13
Household training (dummy)	0.0001***	7.4	0.0001***	2.68	0.0001	-	0.0001***	4.46	0.0001	-	0.0001***	3.62
Central Kampala (dummy)	0.0001***	19.6	0.0001***	7.22	0.0001	-	0.0001***	7.29	0.0001	-	0.0001***	6.68
East region (dummy)	0.0001***	13.8	0.0001***	5.75	0.0001	-	0.0001***	6.75	0.0001	-	0.0001***	6.09
North region (dummy)	0.0001***	15.03	0.0001***	5.71	0.0001	-	0.0001***	5.6	0.0001	-	0.0001***	5.23
Kampala (dummy)	-0.0001***	-7.92	0.0001	-1.51	0.0001	-	0.0001	-1.47	0.0001	-	0.0001	-1.55
Extension	0.0001**	2.42	0.0001	1.11	0.0002	-	0.0001	-0.64	0.0001	-	0.0001***	3.27
Constant	0.5000***	4.60E+04	0.4999***	2.40E+04	0.4999	-	0.4999***	2.60E+04	0.4999	-	0.4999***	2.20E+04
Participation equation												
Extension distance	**-0.0001*** **	**-3.78**	**0.0001**	**-0.64**	**0.0001**	-	**-0.0001**	**-0.91**	**-0.0001**	-	**0.0001**	**0.32**
Year 2010 (dummy)	-0.2714***	-2.58	0.4124*	1.7	-0.4277	-	-5.5899	-0.01	-5.1135	-	0.3399	1
Year 2011 (dummy)	-0.4852***	-3.84	0.5420*	1.73	-4.5526	-	-5.4616	0.01	-4.3458	-	0.2683	0.49
Head age	0.0185	0.9	0.0081	0.15	0.0078	-	0.088	0.5	0.4941	-	0.0396	0.5
Head age square	-0.0001	-0.53	-0.0001	-0.16	0.0001	-	-0.0014	-0.69	-0.005	-	-0.0003	-0.37
Head education	0.0888**	2.29	0.012	0.14	0.0904	-	-0.0185	-0.08	-0.0706	-	-0.0623	-0.53
Head education square	-0.0045*	-1.76	-0.0034	-0.6	0.0007	-	0.0053	0.36	-0.0002	-	0.0085	1.15
Household size	0.0402***	2.71	0.0286	0.86	0.052	-	-0.0289	-0.24	-0.0688	-	0.0132	0.3
Head sex	0.0592	0.5	0.1807	0.68	-0.046	-	0.2287	0.32	0.4255	-	-0.6465*	-1.96
Rural (dummy)	0.4571***	4.06	0.1705	0.61	0.2245	-	5.5967	0.01	0.1966	-	0.3469	0.84
Female share	-0.001	0.01	0.9203	1.1	-3.6045	-	0.7767	0.33	0.4459	-	0.5782	0.47
Female burden share	0.2092	0.55	-0.7433	-0.81	3.1819	-	2.0272	0.93	0.4828	-	0.461	0.36
Household head tribe	-0.0054	-1.56	-0.0016	-0.23	0.0158	-	0.0306	1.2	0.0054	-	0.0147	1.19
Household training (dummy)	0.1429	1.15	0.6411***	2.6	-4.9541	-	0.4208	0.58	-4.6688	-	0.118	0.32
Central Kampala (dummy)	4.4518	0.03	3.5725	0.02	1.8847	-	-13.5508	-0.01	1.9739	-	3.4049	0.01
East region (dummy)	4.7457	0.03	4.1942	0.02	1.5802	-	-8.4642	-0.01	1.5127	-	2.9536	0.01
North region (dummy)	4.5199	0.03	3.028	0.02	1.6125	-	-12.9931	-0.01	-2.9063	-	3.1656	0.01
Kampala (dummy)	4.0308	0.03	3.6844	0.02	2.1634	-	-7.7238	-0.01	1.3534	-	3.9877	0.02
Constant	-6.6941	-0.04	-6.1068	-0.03	-4.9304	-	-2.3831	-0.6	-15.1772	-	-7.7292	-0.03
N	1481		404		404	-	404		404	-	404	
chi2	6562.881		2356.908		-	-	2598.24		-	-	1875.486	
Lambda	-0.0000**	-2.38	0.0001	-1.11	-0.0001	-	0.0001	-0.04	0.0001	-	-0.0001***	-3.14

Rho	-0.6129	-0.6063	-1	-	-0.0193	-0.6457	-	-1
Sigma	0.0001	0.0001	0.0001	-	0.0001	0.0001	-	0.0001

Note: The symbols *, ** and *** indicate 10%, 5% and 1% significance levels, respectively.

Table 7 summarises ATT for six different types of extension programmes. The results indicate that agricultural extension service from large farmers improves productivity – defined in terms of technical efficiency - by 1.02 percent, but we do not find that agricultural extension programmes have improved agricultural productivity in other cases.

Table 7 Summary results of impact estimation (ATT, Average Treatment Effect on Treated)

Dependent variables	Impact variables	Extension services					
		NAADS	NGO	Coop	Large farmer	Input supplier	Others
Productivity (Technical Efficiency)	ATT	-3.26%***	-0.27%***	-1.19%***	1.02***%	-0.29%***	-0.50%***
	Improve?	No	No	No	Yes	No	No
MPCE	ATT	6.58%***	8.37***%	8.64%***	5.37%***	43.43%***	25.88%***
	Improve?	Yes	Yes	Yes	Yes	Yes	Yes
Vulnerability	ATT	-0.001%	-0.0004%**	0.004%***	-0.006%***	-0.002%***	0.002%***
	Reduce?	No	Yes	No	Yes	Yes	No

Notes: The symbols * and *** indicates 10% and 1% significance levels, respectively. The cases of MPCE for Large Farmer and Others are not shown as the result showed an extraordinary large effect.

However, regardless of whether extension services improve agricultural productivity, they are found to increase MPCE in all the cases or reduce poverty significantly, and reduce vulnerability in some cases (namely, NGO, large farmer and input supplier). The percentage increase of the effect of participation in extension programmes on MPCE (after taking account of sample selection) is substantial – ranging from 5.37% to 43.43%. The results at least imply that there are likely to be significant consumption-increasing or poverty-reducing effects expected from participation in extension programmes.

The last row of Table 7 shows that participation in extension services from NGO, large farmer and input supplier significantly reduces household vulnerability. However, the absolute effects are small and vulnerability as an expected poverty is reduced ranging from 0.0004% to 0.006%.

4.4 Poverty and vulnerability incidence in Uganda

This subsection considers categorised incidence of poverty and vulnerability in Uganda. We consider the poverty line of $1.25 and $2.00 per day as a basis of classification of households under poor and non-poor categories. Table 8 summarizes poverty and vulnerability statistics over the years.

Table 8: Poverty and vulnerability incidence in Uganda

			Poverty			Vulnerability
			FGT(0):	FGT(1):	FGT(2):	Mean
2009	US$1.25	Urban	20.8	7.1	3.4	2.3
		Rural	52.8	19.2	9.4	39.2
		Population	44.6	16.1	7.9	29.7
	US$2.00	Urban	36.5	15.0	8.3	17.0
		Rural	79.0	37.4	21.6	69.9
		Population	68.0	31.6	18.1	56.3
2010	US$1.25	Urban	19.2	6.6	3.2	3.3
		Rural	55.1	21.5	11.0	41.3
		Population	47.2	18.2	9.3	32.9
	US$2.00	Urban	39.2	15.2	8.0	19.2
		Rural	79.6	39.5	23.6	72.0
		Population	70.7	34.1	20.2	60.3
2011	US$1.25	Urban	25.1	8.5	4.1	2.9
		Rural	55.5	20.9	10.3	38.8
		Population	49.2	18.4	9.1	31.5
	US$2.00	Urban	48.1	18.7	10.1	20.3
		Rural	78.4	38.8	23.0	68.6
		Population	72.2	34.7	20.3	58.6

FGT(0): headcount ratio (proportion poor)
FGT(1): average normalised poverty gap
FGT(2): average squared normalised poverty gap

First, a substantial share of the population is deemed not only poor, but also vulnerable in Uganda, regardless of which poverty thresholds are adopted. Second, the level of poverty as well as vulnerability remained high over the years. It is noted that poverty gradually increased over the years, for instance, with poverty headcount ratio based on US$1.25 changing from 44.6% in 2009, 47.2% in 2010 and 49.2% in 2011. Third, poverty is concentrated in rural areas as all the poverty figures in rural areas are much higher than those in urban areas. However, it is also noted that urban poverty increased from 2010 to 2011 with the headcount ratio changing based on US$1.25 from 19.2% to 25.1%. While the average levels of vulnerability were much lower than those of poverty head count ratios for both US$1.25 and US$2 lines, a substantial share of the population deemed vulnerable throughout the years.

As we found the overall negative impact of agricultural extension participation on poverty and vulnerability, the extension programs need to be more widely introduced not only for the poor, but also for the vulnerable non-poor to prevent them from slipping into poverty in the future.

Table 9 The Results of OLS model of household characteristics on the poverty (lnMPCE) and vulnerability in Uganda

Variables	Poverty (lnMPCE)		Vulnerability	
	Coef	t value	Coef	t value
Year 2010 (dummy)	-0.0231	-1.2	-0.0001	-0.21
Year 2011 (dummy)	0.1376***	7.21	-0.0001***	-17.93
Head age	0.0019	0.56	-0.0001***	-16.29
Head age square	0.0001	0.52	0.0001***	18.96
Head education	0.0036	0.54	0.0001	0.75
Head education square	0.0029***	5.66	-0.0001***	-10
Household size	-0.0394***	-15	0.0001***	17.15
Head sex	0.0508**	2.5	-0.0001**	-2
Rural (dummy)	-0.2955***	-11.6	0.0001***	15.92
Female share	0.2858***	4.81	-0.0001***	-12.36
Female burden share	-0.7092***	-11.22	0.0002***	21.44
Household head tribe	0.0025***	4.07	-0.0001***	-6.37
Household training (dummy)	0.1811***	5.52	0.0001***	7.76
Central Kampala (dummy)	-0.4644***	-3.37	0.0001***	10.13
East region (dummy)	-0.5020***	-3.64	0.0001***	8.54
North region (dummy)	-0.3716***	-2.7	0.0001***	7.42
Kampala (dummy)	-0.0486	-0.35	-0.0001***	-3.21
Constant	11.1478***	68.85	0.50***	4.00E+04
N	5338		1205	
Adj R-squared	0.2355		0.8422	
F statistics	97.70***	(17, 5320)	379.04***	(17, 1187)

Note: The symbols *, ** and *** indicates 10%, 5%, and 1% significance levels, respectively.

In separate exercises, we have added three proxies for agricultural productivity, namely, yield per hectare, net profit and technical efficiency in regressing log MPCE – as a proxy for poverty - or vulnerability. Both fixed-effects model and random effects model have been estimated. The results are presented in Table 10. In the specifications where log MPCE is a dependent variable (Cases 1 to 6), we have found that improvement in agricultural productivity tends to lead a statistically significant increase in log MPCE, implying that poverty reduces as a result of improvement in agricultural productivity. The coefficient estimates are statistically significant in all the cases.[11] However, none of these proxies of

[11] MPCE in this context is defined as a broad measure of household wellbeing and thus considered to be indirectly affected by improvement in agricultural productivity. We do not impose any theoretical underpinnings (e.g. underlying consumption supply function) for this specification.

agricultural productivity is found to be significant in Cases 7 to 12, suggesting that improvement in agricultural productivity does not lead to statistically significant reduction in vulnerability, which is defined as risk of falling into poverty, while the coefficient estimate is negative in all these cases. That is, an overall improvement in productivity will reduce static poverty, but it will not prevent households from falling into poverty or reduce risk faced by them.

Table 10 Results of panel fixed-effects model on log MPCE and vulnerability with proxies for agricultural productivity

Poverty

VARIABLES	Case 1 FE Log MPCE	Case 2 RE Log MPCE	Case 3 FE Log MPCE	Case 4 RE Log MPCE	Case 5 FE Log MPCE	Case 6 RE Log MPCE
Ln Yield	**0.0129***	**0.0178*****				
(output per ha)	**(0.00766)**	**(0.00650)**				
Ln PROFIT			**0.0129***	**0.0178*****		
(net profit per ha)			**(0.00766)**	**(0.00650)**		
Technical Efficiency					**0.0951*****	**0.158*****
(no restriction)					**(0.0207)**	**(0.0141)**
head_age	0.0357***	0.0110***	0.0357***	0.0110***	0.0267**	0.00456
	(0.0101)	(0.00383)	(0.0101)	(0.00383)	(0.0119)	(0.00407)
head_age2	-0.000282***	-6.83e-05*	-0.000282***	-6.83e-05*	-0.000222**	-8.27e-06
	(9.30e-05)	(3.67e-05)	(9.30e-05)	(3.67e-05)	(0.000107)	(3.92e-05)
head_edu	0.0430***	0.0199***	0.0430***	0.0199***	0.0415***	0.0151**
	(0.00996)	(0.00660)	(0.00996)	(0.00660)	(0.0117)	(0.00711)
head_edu2	-0.00194**	0.00176***	-0.00194**	0.00176***	-0.00226**	0.00197***
	(0.000818)	(0.000531)	(0.000818)	(0.000531)	(0.000948)	(0.000565)
Household Size	-0.103***	-0.0560***	-0.103***	-0.0560***	-0.102***	-0.0611***
	(0.00592)	(0.00302)	(0.00592)	(0.00302)	(0.00711)	(0.00332)
Sex of Head	0.0208	0.0411*	0.0208	0.0411*	0.0310	-0.00285
	(0.0538)	(0.0236)	(0.0538)	(0.0236)	(0.0636)	(0.0250)
cenkam	0.198	-0.0925	0.198	-0.0925	0.198	-0.258
	(0.242)	(0.145)	(0.242)	(0.145)	(0.271)	(0.157)
east	-0.446	-0.479***	-0.446	-0.479***		-0.594***
	(0.608)	(0.146)	(0.608)	(0.146)		(0.158)
north	0	-0.507***		-0.507***		-0.668***
	(0)	(0.146)		(0.146)		(0.158)
kam	0	-0.424***		-0.424***		-0.568***
	(0)	(0.146)		(0.146)		(0.158)
Rural	0.0199	-0.270***	0.0199	-0.270***	-0.0686	-0.347***
	(0.0732)	(0.0295)	(0.0732)	(0.0295)	(0.0824)	(0.0310)
burden_share_female	-0.0326	-0.484***	-0.0326	-0.484***	0.0679	-0.476***
	(0.102)	(0.0643)	(0.102)	(0.0643)	(0.129)	(0.0711)
female_share	-0.184	0.118*	-0.184	0.118*	-0.174	0.142**
	(0.113)	(0.0638)	(0.113)	(0.0638)	(0.141)	(0.0696)
2009b.year	0	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)	(0)
2010.year	-0.00173	-0.0215	-0.00173	-0.0215	0.0112	-0.0161
	(0.0149)	(0.0144)	(0.0149)	(0.0144)	(0.0174)	(0.0162)

2011.year	0.144***	0.134***	0.144***	0.134***	0.167***	0.169***
	(0.0154)	(0.0144)	(0.0154)	(0.0144)	(0.0181)	(0.0161)
Constant	10.23***	11.04***	10.23***	11.04***	9.346***	9.620***
	(0.326)	(0.178)	(0.326)	(0.178)	(0.416)	(0.241)
Observations	5,822	5,822	5,822	5,822	4,720	4,720
R-squared	0.123		0.123		0.118	
Number of HHID	2,356	2,356	2,356	2,356	2,220	2,220

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

VARIABLES	Case 7 FE vulnerability	Case 8 RE vulnerability	Case 9 FE vulnerability	Case 10 RE vulnerability	Case 11 FE vulnerability	Case 12 RE vulnerability
Ln Yield (output per ha)	**-6.44e-07**	**7.89e-08**				
	(9.81e-07)	**(6.75e-07)**				
Ln PROFIT (net profit per ha)			**-6.44e-07**	**7.89e-08**		
			(9.81e-07)	**(6.75e-07)**		
Technical Efficiency (no restriction)					**-2.57e-06**	**-1.31e-06**
					(2.68e-06)	**(1.33e-06)**
head_age	-9.20e-06***	-5.42e-06***	-9.20e-06***	-5.42e-06***	-8.98e-06***	-5.35e-06***
	(1.73e-06)	(3.87e-07)	(1.73e-06)	(3.87e-07)	(2.30e-06)	(4.17e-07)
head_age2	8.93e-08***	6.09e-08***	8.93e-08***	6.09e-08***	8.89e-08***	5.95e-08***
	(1.62e-08)	(3.72e-09)	(1.62e-08)	(3.72e-09)	(2.10e-08)	(4.03e-09)
head_edu	2.03e-06	1.22e-06*	2.03e-06	1.22e-06*	1.53e-06	7.41e-07
	(1.49e-06)	(6.71e-07)	(1.49e-06)	(6.71e-07)	(2.01e-06)	(7.37e-07)
head_edu2	-5.57e-07***	-4.64e-07***	-5.57e-07***	-4.64e-07***	-5.10e-07***	-4.23e-07***
	(8.92e-08)	(4.50e-08)	(8.92e-08)	(4.50e-08)	(1.18e-07)	(4.91e-08)
Household Size	4.28e-06***	3.99e-06***	4.28e-06***	3.99e-06***	6.31e-06***	4.46e-06***
	(7.50e-07)	(2.87e-07)	(7.50e-07)	(2.87e-07)	(1.01e-06)	(3.16e-07)
Sex of Head	7.35e-06	-2.12e-06	7.35e-06	-2.12e-06	5.93e-06	-1.23e-06
	(6.76e-06)	(2.22e-06)	(6.76e-06)	(2.22e-06)	(7.94e-06)	(2.40e-06)
cenkam	2.01e-05	-1.96e-05**	2.01e-05	-1.96e-05**	2.47e-05	-2.24e-05**
	(1.81e-05)	(9.33e-06)	Sex	(9.33e-06)	(1.95e-05)	(9.29e-06)
east		9.17e-05***		9.17e-05***		9.19e-05***
		(9.46e-06)		(9.46e-06)		(9.42e-06)
north		7.38e-05***		7.38e-05***		7.34e-05***
		(9.49e-06)		(9.49e-06)		(9.45e-06)
kam		6.89e-05***		6.89e-05***		6.94e-05***
		(9.38e-06)		(9.38e-06)		(9.32e-06)
Rural	3.36e-05***	2.95e-05***	3.36e-05***	2.95e-05***	4.74e-05***	2.98e-05***
	(1.26e-05)	(2.39e-06)	(1.26e-05)	(2.39e-06)	(1.50e-05)	(2.56e-06)
burden_share_female	0.000161***	0.000152***	0.000161***	0.000152***	0.000153***	0.000152***
	(1.51e-05)	(7.42e-06)	(1.51e-05)	(7.42e-06)	(1.87e-05)	(8.21e-06)
female_share	-5.54e-05***	-7.55e-05***	-5.54e-05***	-7.55e-05***	-3.44e-05	-7.55e-05***
	(1.65e-05)	(6.66e-06)	(1.65e-05)	(6.66e-06)	(2.28e-05)	(7.51e-06)
2009b.year	0	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)	(0)
2010.year	1.66e-06	9.12e-07	1.66e-06	9.12e-07	1.88e-06	9.32e-07
	(1.91e-06)	(1.57e-06)	(1.91e-06)	(1.57e-06)	(2.40e-06)	(1.80e-06)
2011.year	-3.59e-05***	-3.58e-05***	-3.59e-05***	-3.58e-05***	-3.91e-05***	-3.64e-05***
	(2.12e-06)	(1.60e-06)	(2.12e-06)	(1.60e-06)	(2.72e-06)	(1.86e-06)
Constant	0.500***	0.500***	0.500***	0.500***	0.500***	0.500***
	(4.93e-05)	(1.42e-05)	(4.93e-05)	(1.42e-05)	(6.92e-05)	(2.01e-05)
Observations	1,193	1,193	1,193	1,193	971	971
R-squared	0.714		0.714		0.715	
Number of HHID	792	792	792	792	695	695

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

5. Concluding Observations

In this paper we have first examined the relationship between farm size, agricultural productivity and access to agricultural extension programmes in reducing poverty and vulnerability drawing upon the LSMS pane data in Uganda in 2009-2012. We have specifically focused on the relationship between farm size and productivity to see whether smallholders have higher agricultural productivity than large holders. We have also tested whether access to agricultural extension programmes was effective in reducing poverty and vulnerability to derive policy implications. To take account of sample selection bias associated with household participation in extension programmes, we have applied treatment-effects model, a variant of Heckman sample selection model.

The main results of the paper have been summarised as follows. First, we have found a negative association between farm size and agricultural productivity for some proxies for the latter, namely, output per hectare, intensity of land use and net profit per hectare. Such a negative relation has not been found for technical efficiency. Our results imply that smallholders are generally more productive than large-holders and thus it is misleading to consolidate land or neglect smallholders in favour of large farmers on the grounds of economies of scale in crop production as well as marketing.

Second, agricultural productivity was not necessarily improved by participation in government extension programmes called the National Agricultural Advisory Services (NAADS), cooperatives, large farmers and input suppliers extension sources. This is a surprising result that may not be explained easily. One possibility is that it may take some time for these programmes to increase agricultural productivity, which may not be captured by relatively short panel data. Given that our estimations of agricultural productivity by stochastic frontier analysis suggest that there remains inefficiency in agricultural productions, it would be important for the policymakers of government to allocate enough budgets for extension programmes and improve the efficiency of these programmes.

Third, log mean per capita expenditure (MPCE) - our proxy for consumption poverty – was significantly increased by extension program participation. This is consistent with the poverty reducing role of different extension programs. It is also found that vulnerability that has been derived as a probability of the household falling into poverty in the future was reduced by the participation in a few types of extension programs.

Finally, improvement in agricultural productivity will reduce static poverty significantly, while it does not necessarily lead to reduction in household vulnerability. It can be concluded that agricultural policies tailored to local needs, such as agricultural extension programmes, should be thus combined with poverty or vulnerability alleviation policies targeting smallholders or the landless households.

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Appendix 1 Descriptive statistics of different variables used for the estimation
(Number of observations: 8578)

Variable	Minimum	Mean	Maximum	Std.Dev.	Description
Production variables					
Land	0.1	9.59	601.50	19.62	Land cultivated by the household (unit ha)
Labour	0	270.16	9631.00	250.70	Labor used for cultivation
Inputs	0	60498.20	8823358.00	188680.2	Inputs used for cultivation
Outputs	0	9675.749	25100000.00	333189.7	Output from products and by-products
Dependent variables for impact estimation					
Te	0.0009	0.0701	0.2225	0.0819	Technical efficiency estimated by SFA with Cobb-Douglas specification
MPCE	1807.45	68197.82	3095522	91057.75	Mean per capita consumption expenditure
pMPCE	-6214.18	91377.61	1418041	79248.95	Predicted mean per capita consumption expenditure
Vulnerability	0.4980	0.4995	0.5000	0.0004	Vulnerability of household
Variance _pMPCE	2.37E+07	9.32E+07	1.67E+10	4.59E+08	Variance of pMPCE
Household variables					
Head age	13	45.7527	100	15.2082	Age of household head
Head education	0	5.0764	15	4.1024	Educational level of household head
Household size	0	6.2016	29	3.3254	Number of family members of the household
Head sex	0	0.7028	1	0.4570	Sex of household head 0=female, 1=male
Household head tribe	2	32.7973	68	15.6035	Tribe of household head
Region-Central Kampala	0	0.2315	1	0.4218	Dummy for central region except Kampala
Region-East	0	0.2497	1	0.4329	Dummy for eastern region
Region-North	0	0.2079	1	0.4058	Dummy for northern region
Region-Kampala	0	0.2566	1	0.4368	Dummy for Kampala region
Region-West	0	0.2079	1	0.4058	Dummy for western region
Rural/Urban	0	0.7701	1	0.4208	Dummy for rural area 0=urban, 1=rural
Household training	0	0.0838	1	0.2771	Dummy for training of household members; 0=no, 1=yes
Female burden share	0	0.2468	1	0.1994	Share of female members within age of below 15 and above 64 to the total household members
Female share	0	0.5098	1	0.2208	Share of female members to the total household members
Access to Extension Programmes					
Variable	Minimum	Mean	Maximum	Std.Dev.	Description
(i) NAADS	0	0.1390	1	0.3460	Whether any household member had access to extension services from

					NAADS
(ii) NGO	0	0.0813	1	0.2733	Whether any household member had access to extension services from NGO
(iii) Cooperatives	0	0.0377	1	0.1904	Whether any household member had access to extension services from Cooperatives
(iv) Input suppliers	0	0.0230	1	0.1499	Whether any household member had access to extension services from Large Farmers
(v) Large farmers	0	0.0155	1	0.1234	Whether any household member had access to extension services from Input Suppliers
(iv) Others	0	0.0333	1	0.1795	Whether any household member had access to extension services from Other Sources
Access to Extension Programmes by region					
Central Kampala (Number of Observations: 4781)					
(i) NAADS	0	0.0736	1	0.2612	Whether any household member had access to extension services from NAADS
(ii) NGO	0	0.0756	1	0.2646	Whether any household member had access to extension services from NGO
(iii) Cooperatives	0	0.0717	1	0.2583	Whether any household member had access to extension services from Cooperatives
(iv) Large farmers	0	0.0330	1	0.1787	Whether any household member had access to extension services from Large Farmers
(v) Input suppliers	0	0.0291	1	0.1682	Whether any household member had access to extension services from Input Suppliers
(iv) Others	0	0.0620	1	0.2414	Whether any household member had access to extension services from Other Sources
East (Number of Observations: 5166)					
(i) NAADS	0	0.1370	1	0.3439	Whether any household member had access to extension services from NAADS
(ii) NGO	0	0.0660	1	0.2485	Whether any household member had access to extension services from NGO
(iii) Cooperatives	0	0.0550	1	0.2282	Whether any household member had access to extension services from Cooperatives
(iv) Large farmers	0	0.0079	1	0.0884	Whether any household member had access to extension services from Large Farmers
(v) Input suppliers	0	0.0220	1	0.1468	Whether any household member had access to extension services from Input Suppliers
(iv) Others	0	0.0487	1	0.2155	Whether any household member had access to extension services from Other Sources
North (Number of Observations: 6192)					
(i) NAADS	0	0.2143	1	0.4104	Whether any household member had access to extension services from NAADS
(ii) NGO	0	0.1222	1	0.3278	Whether any household member had access to extension services from NGO
(iii) Cooperatives	0	0.0185	1	0.1349	Whether any household member had access to extension services from Cooperatives
(iv) Large farmers	0	0.0358	1	0.1859	Whether any household member had access to extension services from Large Farmers
(v) Input suppliers	0	0.0074	1	0.0858	Whether any household member had access to extension services from Input Suppliers
(iv) Others	0	0.0160	1	0.1257	Whether any household member had access to extension services from Other Sources
Kampala (Number of Observations: 11)					
(i) NAADS	0	0	0	0	Whether any household member had access to extension services from NAADS
(ii) NGO	0	0	0	0	Whether any household member had access to extension services from NGO
(iii) Cooperatives	0	0	0	0	Whether any household member had access to extension services from Cooperatives
(iv) Large farmers	0	0.09099	1	0.3000	Whether any household member had access to extension services from Large Farmers

(v) Input suppliers	0	0	0	0	Whether any household member had access to extension services from Input Suppliers
(iv) Others	0	0	0	0	Whether any household member had access to extension services from Other Sources
West (Number of Observations: 4513)					
(i) NAADS	0	0.1666	1	0.3700	Whether any household member had access to extension services from NAADS
(ii) NGO	0	0.0440	1	0.2100	Whether any household member had access to extension services from NGO
(iii) Cooperatives	0	0.0128	1	0.1100	Whether any household member had access to extension services from Cooperatives
(iv) Large farmers	0	0.0110	1	0.1000	Whether any household member had access to extension services from Large Farmers
(v) Input suppliers	0	0.0073	1	0.0900	Whether any household member had access to extension services from Input Suppliers
(iv) Others	0	0.0147	1	0.1200	Whether any household member had access to extension services from Other Sources

Appendix 2 Correlation between Instrument (distance from village centre to extension service) with Outcome Variables and Variables on Extension

Variables	Correlation coefficient
Outcome variables	
Technical efficiency	0.0548
MPCE	0.0214
Vulnerability	-0.0435
Extension variables	
(i) NAADS	-0.1261
(ii) NGO	-0.0623
(iii) Cooperatives	-0.0109
(iv) Large farmers	-0.0338
(v) Input suppliers	-0.0123
(iv) Others	-0.0033