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Abstract

The present study examines whether agricultural extension improves household crop productivity and reduces poverty and vulnerability in rural Uganda drawing upon Uganda National Panel Survey data in 2009-10. We first estimate household crop productivity using stochastic frontier analysis that can allow for stochastic shocks in the production function. Then, 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. In this model, the distance to agricultural extension service centre is used as an instrument for participation equation. It is found that participation in agricultural extension programs significantly raised crop productivity and household expenditure per capita in most cases with a few exceptions. This is consistent with the central objectives of agricultural extension to improve productivity and reduce poverty. Further evidence has been provided on the role of most types of agricultural extension in reducing vulnerability as expected poverty.

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

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

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1. Introduction

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, most of the agricultural sectors in less developed countries have 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 in some African countries that face budget constraints (Ndegwa, 2002).

Many countries in sub-Saharan Africa including Uganda still rely on agriculture as a leading force of economic growth and poverty reduction. About 31.1 percent of Ugandans were estimated to be poor, corresponding to nearly 8.4 million people (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, 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).

In Uganda, reformation of 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 the sub-national or regional level, 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, the present study will examine whether the transformation of agricultural extension policy has been successful to improve farm households' livelihood in terms of productivity improvement as well as poverty and/or vulnerability reduction. We will also compare the impact of participation in NAADS or government extension programmes, NGO extension programmes, and other different types of agricultural extension supported, for instance, by cooperatives, large farmers, or input suppliers to identify the effect of the policy reform on effectiveness of agricultural extension. The present study thus aims at (i) estimating the current level of crop productivity and potentials for further improvement, (ii) comparing the impacts of participation in different extension programmes on crop productivity provided by different actors, and (iii) examining the impacts of participation in different extension programmes on mean per capita consumption expenditure 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 data set of Uganda National Panel Survey (UNPS) conducted by the Uganda Bureau of Statistics (UBOS) in 2009-2010. The survey was financially and technically supported by the Government of Netherlands, and the World Bank Living Standards Measurement Study - Integrated Surveys on Agriculture (LSMS-ISA) project. The first 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.

3. Methodology

3.1 Household crop productivity estimation

The effectiveness of agricultural extension programs on household crop productivity is estimated by adopting the two step procedure. In the first step, crop productivity aggregated at household level is estimated to examine whether there is any room for further productivity improvement. 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). In case of cross sectional data, the inefficiency component is supposed to represent the productivity.

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); and *i* is the individual farmer.

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_i) 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_i), 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, thus the estimation by 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

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

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

3.2 Impact of extension programs on crop productivity

In the second step, 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 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).

On the other hand, 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 the 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

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

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

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 ν_i of (5), the correlation coefficient between ε_i and ν_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

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

where the expected outcome for the participants is

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

and the expected outcome for the non-participants is

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

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*,

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

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

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

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

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

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.

3.3 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 as described in the sub-section (3.2).

3.3.1 Deriving Vulnerability Measure

Vulnerability measure as an expected poverty is specified as:

$$VEP_{it} \equiv V_{it} = \Pr\left(c_{i,t+1} \leq z\right) \qquad (13)$$

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*, $c_{i,t+1}$, 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).[1]

$$\ln c_i = X_i \lambda + e_i \quad (14)$$

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:

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

The estimates of β and θ are obtained using a three-step feasible generalized least squares (FGLS)[2]. 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.

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

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

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

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1 We have used White-Huber sandwich estimator to overcome heteroscedasticity in the sample.

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

be poor in the future (say, at time *t+1*) is given by:

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

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 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. Econometric results

4.1 Household crop 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 0.44 to 0.45 for land, 0.42 to 0.49 for labour and 0.14 to 0.15 for other inputs.

(Table 1 to be inserted around here)

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 (3) 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 22 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 to be inserted around here)

4.2 Impact of extension program participation 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 3, those on log MPCE in Table 4 and those on vulnerability in Table 5 respectively. Table 6 summarises the average treatment effect on treated (ATT) derived by treatment effects model (the results of which are shown in Tables 3, 4 and 5) as well as whether extension program improves productivity and log MPCE and reduces vulnerability.

(Tables 3, 4, 5 and 6 to be inserted around here)

In Tables 3, 4 and 5, 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 3, 4 and 5.[3] 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 (NGO extension programme participation is significant at exactly 10% significance level for Table 5 - vulnerability model), while positive and significant 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. Again, a longer distance to the formal extension service centre emboldens the cooperatives program participation, which validates our specification. However, 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, non-government and cooperative extension programmes, but not others. Though statistically not significant, the coefficient estimate of the distance to extension service centre is positive for (v) Input suppliers in Tables 3 and 5. This implies that farmers tend to seek different providers if the village is located far away from the extension

[3] The results of probit model in the first stage are similar for Table 3, Table 4 and Table 5, but not identical as (i) the number of observations is different depending on the availability of outcome variables and (ii) we have adopted the full maximum likelihood estimation in which unlike two step estimation the first stage results are allowed to be influenced by the second regressions in iteration processes.

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 Table A2 in Appendix).[4]

To summarise the coefficient estimates of selected explanatory variables in Tables 3, 4 and 5, the participants on NAADS following the second panels of these tables are likely to be older, more educated, from a larger household and households that has more members with training. Similarly, better educated household heads tend to participate in NGO extension programmes more likely than less educated heads. That is, education is a fundamental determinant for participation in NAADS and NGO programmes. Larger households are more likely to be supported by NAADS, NGO and Cooperatives than smaller households. Geographical location appears to be a main determinant of extension services from large farmers, input suppliers and "others" because they tend to concentrate in specific regions ((iv), (v) and (vi) in Table 3).

The first panel of Tables 3, 4, and 5 reports the results of the second stage regressions. It is generally observed in Table 3 that crop productivity is positively affected by household head's education ((ii), (iii), (v) and (vi)), male headedness (all cases), household size (except (i)), and female share ((ii)-(v)), whilst negatively affected by 'belonging to tribe 1' ((ii)-(v)) and a higher dependency rate for female members ((ii)-(v)). The results are mostly expected except a positive and significant coefficient estimate of the share of female members. This may imply an important role played by women in working age in increasing agricultural productivity.

[4] 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.

The first panel of Table 4 shows the results of the second stage regressions for log MPCE. Expenditure is positively affected by the household having more members who received training (except (i) NAADS), and a higher share of female members. On the other hand, it is negatively influenced by household size and by a higher burden share of female members. In Table 5, we find that a household with a younger and/or less educated household head tends to be more vulnerable. Having more household members is likely to make the household more vulnerable. As expected, a household headed by a woman is more likely to be vulnerable to future poverty. Having more members with training is positively associated with higher vulnerability, but this is presumably because training programmes have targeted poor households. Households under tribe 1 are significantly vulnerable to poverty in future time. Regional variation in vulnerability is observed across different extension models.

Table 6 summarises ATT for six different types of extension services. The results indicate that participation in government agricultural extension service (NAADS) improves productivity about 3.42 percent. The percentage improvement varies among different types of providers: +9.94 percent for Cooperatives, +1.96 percent for Large Farmers and +6.89 percent for Input Suppliers. The extension service received from "Other" sources of extension services showed negative impact on productivity. It is noted that extension service from cooperatives has the largest impact on productivity improvement. NAADS programs are more effective compared to NGO programs for productivity improvement. Given the low level of agricultural productivity, the average improvement of productivity by 3.42% is substantial and supports the hypothesis that government extension service was effective in improving household's crop productivity.

However, the productivity improvement may not necessarily lead to poverty or vulnerability reduction directly and so we have estimated the treatment effects of agricultural extension programmes on MPCE and vulnerability. On log MPCE, access to all types of extension service reception increased household expenditure significantly (except extension service received from NGO). The percentage increase of the effect of participation in extension programmes on MPCE (after taking account of sample selection) is substantial – ranging from 9.75% to 112.32%. However, it should be noted that calculations of ATT are based on cross-sectional data for the two samples with or without access to extension programmes and the results do not necessarily suggest that access to extension programmes suddenly increases MPCE. However, 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 6 shows that participation in all types of program participation significantly reduces household vulnerability (except input suppliers). However, the absolute effects are small and vulnerability as an expected poverty is reduced ranged from 0.38% to 3.79%. Our results serve as another piece of evidence to show the effectiveness of NAADS in reducing vulnerability.

4.3 Poverty and vulnerability incidence in Uganda

This section considers categorised incidence of poverty and vulnerability in Uganda. We consider the poverty line of $1.25 per day as a basis of classification of households under poor and non-poor categories. For classification of households according to vulnerability incidence we used mean ± standard deviation (0.3724 ± 0.0568) of overall (whole sample) vulnerability. The results are presented in Table 7.

(Table 7 to be inserted around here)

The most important point to note in Table 7 is that, although 76.70 percent of the sample households surveyed by the UNPS in Uganda in 2009-10 were poor, about 16.82

percent were highly vulnerable to poverty and the other 66.44 percent moderately vulnerable. In other words, vulnerability is more widespread than poverty in Uganda. This result implies that a substantial share in the population has a risk of falling into poverty, even if they are not currently poor. Again, the poor constitute 77 percent of the sample, and about 14 percent (143 out of 994) of those are highly vulnerable. On the other hand, about 25 percent (75 out of 302) of non-poor are highly vulnerable and have a risk of falling into poverty in future time. As we found the negative impact of agricultural extension participation on 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. Education is found to be negative and significant in explaining vulnerability, but it is not significant for poverty (or log MPCE) as shown in Table A3 in Appendix. It is implied by these results that educational programs might need to be strengthened in Uganda to reduce vulnerability to poverty. Table A3 also indicates that the household headed by a female member tends to be more vulnerable. In allocating agricultural extension programmes, prioritising female-headed households would be necessary as one of the policy measures to help them avoid falling into poverty.

5. Concluding Observations

The present study has examined whether participation in different agricultural extension programs has any effect on household crop productivity, poverty, or vulnerability in Uganda. 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.

It is found that household crop productivity was significantly improved by participation in government extension programmes called the National Agricultural Advisory

Services (NAADS), cooperatives, large farmers and input suppliers extension sources. Our results show that the NAADS programs are more effective in productivity improvement compared to NGO programs. This would serve as indirect evidence to show that the reform of agricultural extension which government has undertaken using a decentralized, demand-driven, client oriented and farmer-led approach was successful in increasing the efficiency and quality of the agricultural extension services. However, 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 NAADS programmes so that poor households can have access to these programmes for the duration to exist from poverty.

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 extension programs. The share of vulnerable households is much higher than the poverty incidence in rural Uganda and education was found to be the key to reducing the former.

Because the results are mixed, we cannot derive a single conclusion, but some of the results on poverty and vulnerability are consistent with the recent observation that agricultural extension programs play a central role in helping poor agricultural households improve crop productivity and escape from poverty. The present study implies that the policy interventions to improve agricultural household' livelihood through agricultural extension services would potentially raise crop productivity and reduce not only poverty but also vulnerability.

One of the distinct contributions of the present study is that we disaggregated the effects of agricultural extension programmes by the type of providers and showed the effectiveness of governmental programmes of agricultural extension in improving crop productivity and reducing poverty and vulnerability. However, our results are based on the cross-sectional data and are subject to the caveat that we have not analysed the welfare or productivity changes of households before or after the participation in extension services. As inefficiency in agricultural production as well as poverty still persists, the future study should examine the role of agricultural extension with panel data.

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Table 1: Results of stochastic frontier analysis

Variables	Cobb-Douglas		Cobb-Douglas –CRS	
	Coeff.	SE	Coeff.	SE
Constant	13.2103***	0.4449	13.7120***	0.2523
lnLand	0.4542***	0.0530	0.4393***	0.0516
lnLabor	0.4915***	0.0742	0.4229***	0.0544
lnInput	0.1462***	0.0282	0.1378***	0.0274
Sigma_v	0.8414	0.0509	0.8273	0.0493
Sigma_u	3.5385	0.0907	3.5574	0.0895
Sigma2	13.2288	0.6120	13.3392	0.6105
Lambda	4.2056	0.1206	4.3001	0.1176
Wald Chi2	299.65***		1001.37***	
Obs. No.	1454		1454	
LR statistics	2.8e+02***			

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

Table 2: Descriptive statistics of technical efficiency of different models

Models	Obs	Mean	Std. Dev.	Min	Max
Cobb-Douglas	1454	0.2199	0.1998	0.00004	0.8276
Cobb-Douglas -CRS	1454	0.2190	0.2008	0.00004	0.8247

Table 3. The Results of Treatment Effects Model on the Effects of Agricultural Extension Programs Participation on Household Crop Productivity in Uganda

	(i)NAADS (Government)		(ii) NGO		(iii) Cooperatives		(iv) Large farmer		(v) Input supplier		(vi) Others	
Variables	Coef.	Z value	Coef.	Z value	Coef.	Z value	Coef.	Z value	Coef.	Z value	Coef.	Z value
Impact equation												
Head age	-0.0025	-0.79	0.0013	0.47	0.0014	0.54	0.0005	0.18	0.0014	0.54	0.0006	0.23
Head age square	0.00001	0.45	-0.00002	-0.73	-0.00001	-0.75	-9.53e-06	-0.36	-0.00002	-0.77	-0.00001	-0.45
Head education	-0.00004	-0.01	0.0120	2.21**	0.0096	1.82*	0.0084	1.53	0.0096	1.81*	0.0100	1.82*
Head education square	-0.00002	-0.04	-0.0003	-0.80	-0.0002	-0.54	-0.0001	-0.30	-0.0002	-0.52	-0.0004	-0.80
Household size	0.0009	0.38	0.0053	2.45**	0.0045	2.10**	0.0045	2.06**	0.0044	2.11**	0.0043	2.00**
Head sex	0.0417	2.12**	0.0399	2.28**	0.0410	2.39**	0.0388	2.16**	0.0425	2.47**	0.0380	2.13**
Household tribe 1	-0.0169	-0.83	-0.0399	-2.21**	-0.0319	-1.78*	-0.0333	-1.81*	-0.0344	-1.94*	-0.0234	-1.28
Household tribe 2	-0.0009	-0.04	-0.0322	-1.56	-0.0188	-0.93	-0.0197	-0.95	-0.0192	-0.97	-0.0114	-0.55
Region-Central Kampala	0.0112	0.47	-0.0160	-0.76	-0.0265	-1.28	-0.0468	-2.20**	-0.0213	-1.02	-0.0460	-2.17**
Region-East	-0.0595	-2.82***	-0.0522	-2.76***	-0.0609	-3.28***	-0.0711	-3.69***	-0.0594	-3.22***	-0.0681	-3.56***
Region-North	-0.1304	-5.19***	-0.0788	-3.30***	-0.1070	-4.86***	-0.1067	-4.71***	-0.1025	-4.64***	-0.1103	-4.90***
Region-Kampala	0.2641	2.03**	0.0819	0.72	0.0958	0.87	0.1018	0.88	0.1185	1.04	0.0934	0.81
Rural/Urban	0.0412	1.65	0.0279	1.25	0.0297	1.36	0.0428	1.88*	0.0296	1.35	0.0276	1.22
Household training	-0.0489	-1.93*	-0.0057	-0.26	-0.0141	-0.66	-0.0040	-0.18	-0.0111	-0.51	-0.0014	-0.06
Female burden share	-0.0652	-1.06	-0.1154	-2.1**	-0.0964	-1.81*	-0.0956	-1.71*	-0.0903	-1.68*	-0.0714	-1.28
Female share	0.0680	1.20	0.1161	2.29**	0.0989	2.01**	0.0869	1.68*	0.0959	1.93*	0.0742	1.44
Extension	**0.2802**	**6.13*** **	**-0.1820**	**-3.05*** **	**0.0131**	**0.17**	**0.4590**	**12.84*** **	**-0.0719**	**-0.90**	**0.3861**	**9.76*** **
Constant	0.1701	2.05**	0.1014	1.38	0.1022	1.43	0.1149	1.53	0.1026	1.43	0.1272	1.7*
Participation equation												
Distance to extension centre	**-0.0001**	**-2.83*** **	**-0.0002**	**-1.79***	**0.0001**	**1.91***	**-0.0001**	**-1.12**	**0.00003**	**0.32**	**-0.00006**	**-0.80**
Head age	0.0491	2.38**	0.0013	0.04	0.0151	0.39	0.0157	0.36	0.0591	1.03	0.0306	0.74
Head age square	-0.0004	-2.16**	-0.0001	-0.31	-0.0002	-0.4	-0.0002	-0.50	-0.0008	-1.24	-0.0002	-0.60
Head education	0.0867	2.25**	0.1353	2.12**	-0.0005	-0.01	0.0116	0.17	0.0688	0.69	0.0350	0.48
Head education square	-0.0014	-0.47	-0.0069	-1.45	0.0013	0.21	-0.0013	-0.25	-0.0024	-0.35	-0.0013	-0.25
Household size	0.0384	2.46**	0.0445	1.94*	0.0591	2.21**	0.0065	0.24	-0.0425	-1.08	0.0125	0.49
Head sex	0.0018	0.01	-0.1716	-0.85	0.3705	1.17	-0.0943	-0.45	0.2169	0.66	0.1024	0.40
Household tribe 1	-0.1227	-0.93	-0.5368	-2.55**	-0.6236	-2.59**	0.0797	0.38	-0.6549	-2.06**	-0.0888	-0.41
Household tribe 2	-0.1606	-1.10	-0.9783	-3.57***	-0.9714	-2.81***	-0.0704	-0.30	-0.0729	-0.21	-0.1633	-0.63
Region-Central Kampala	-0.4579	-2.96***	0.8226	3.09***	0.7366	2.61***	0.7492	2.51**	1.6686	3.34***	0.5786	2.36**
Region-East	-0.1263	-0.93	0.5788	2.40**	0.5971	2.18**	0.7351	2.46**	0.7389	1.46	0.1991	0.77
Region-North	0.1819	1.16	1.7114	5.45***	1.0841	2.79***	0.5700	1.58	1.4142	2.62***	0.2686	0.84
Region-Kampala	-5.7167	-0.00	-3.0770	-0.00	-9.9846	0	-2.4671	.	2.5384	2.21**	-2.7470	.
Rural/Urban	0.0002	0.00	0.0615	0.27	0.1445	0.43	-0.0793	-0.29	-0.1900	-0.57	0.0257	0.09
Household training	0.3371	2.26**	0.3172	1.65*	0.2334	0.94	-3.8096	.	0.4687	1.89*	-6.4296	.
Female burden share	-0.4650	-1.20	-1.0727	-1.79*	0.8106	0.93	0.3836	0.54	1.7863	1.98**	-0.8879	-1.20
Female share	0.4356	1.21	0.9575	1.77*	-0.2892	-0.35	0.0583	0.08	-1.0435	-1.29	0.5932	0.81
Extension	-2.2771	-4.17***	-2.5344	-2.91***	-3.4811	-3.17***	-2.4241	-2.20**	-3.9153	-2.68***	-3.1821	-2.84***
athrho	-0.8330	-4.88***	0.4586	2.61***	0.1898	1.04	-1.3885	-7.33***	0.2358	1.18	-1.2515	-6.65***
lnsigma	-1.5537	-29.16***	-1.6711	-58.75***	-1.6934	-70.89***	-1.6457	-66.04***	-1.6892	-70.30***	-1.6513	-66.45***
N	924		924		924		924		924		924	
Rho	-0.6821		0.4289		0.1876		-0.8828		0.2315		-0.8487	
Sigma	0.2115		0.1880		0.1839		0.1929		0.1847		0.1918	
Lambda	-0.1442		0.0807		0.0345		-0.1703		0.0428		-0.1628	
LR statistics	7.78	***	3.81	*	0.86		20.67	***	1.01		10.67	***
Wald Chi2	122.80	***	117.06	***	112.70	***	267.26	***	112.54	***	198.85	***

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

Table 4. The Results of Treatment Effects Model on the Effects of Agricultural Extension Programs Participation on log MPCE in Uganda

Variables	(i)NAADS (Government) Coef.	Z value	(ii) NGO Coef.	Z value	(iii) Cooperatives Coef.	Z value	(iv) Large farmer Coef.	Z value	(v) Input supplier Coef.	Z value	(vi) Others Coef.	Z value
Impact equation												
Head age	0.0013	0.11	0.0094	0.81	0.0090	0.78	0.0114	0.95	0.0094	0.78	0.0122	1.01
Head age square	2.51e-06	0.02	-0.0001	-0.55	-0.0001	-0.56	-0.0001	-0.75	-0.0001	-0.66	-0.0001	-0.77
Head education	-0.0124	-0.48	-0.0001	-0.01	0.0067	0.29	0.0097	0.40	0.0069	0.29	0.0050	0.21
Head education square	0.0020	1.09	0.0020	1.06	0.0016	0.87	0.0014	0.74	0.0018	0.92	0.0022	1.12
Household size	-0.0482	-4.80***	-0.0430	-4.66***	-0.0446	-4.80***	-0.0409	-4.33***	-0.0432	-4.53***	-0.0402	-4.21***
Head sex	-0.0704	-0.92	-0.0673	-0.89	-0.0844	-1.12	-0.0646	-0.83	-0.0475	-0.61	-0.0577	-0.74
Household tribe 1	-0.3430	-4.29***	-0.3538	-4.53***	-0.3406	-4.33***	-0.3720	-4.67***	-0.4108	-5.11***	-0.4118	-5.11***
Household tribe 2	-0.2260	-2.50**	-0.2290	-2.57**	-0.2228	-2.50**	-0.2632	-2.93***	-0.2553	-2.81***	-0.2974	-3.27***
Region-Central Kampala	0.6365	6.47***	0.5361	5.95***	0.5246	5.79***	0.6183	6.71***	0.6501	6.99***	0.6465	6.94***
Region-East	0.1270	1.55	0.1027	1.26	0.1001	1.23	0.1533	1.84*	0.1451	1.72*	0.1570	1.86*
Region-North	0.0704	0.71	0.0428	0.41	0.0804	0.83	0.1193	1.22	0.1919	1.93*	0.1350	1.36
Region-Kampala	0.8367	1.59	0.5414	1.11	0.4920	1.01	0.4873	0.97	0.9412	1.85*	0.5132	1.01
Rural/Urban	0.1401	1.43	0.1233	1.29	0.1052	1.10	0.0836	0.85	0.1104	1.11	0.1271	1.27
Household training	0.1571	1.53	0.2039	2.14**	0.2155	2.28**	0.2006	2.06**	0.2812	2.85***	0.1750	1.77*
Female burden share	-0.8343	-3.48***	-0.8422	-3.56***	-0.9150	-3.91***	-0.8965	-3.70***	-0.7845	-3.21***	-0.9968	-4.07***
Female share	0.4129	1.86*	0.4268	1.95*	0.4758	2.20**	0.5056	2.26**	0.4167	1.84*	0.5759	2.54**
Extension	**0.5569**	**1.86***	**0.4995**	**1.86***	**0.6580**	**2.02****	**-1.2084**	**-6.08*****	**-1.4023**	**-10.04*****	**-1.5931**	**-10.14*****
Constant	6.4229	19.59***	6.2876	19.91***	6.3150	20.06***	6.2519	19.21***	6.3057	19.21***	6.1816	18.78***
Participation equation												
Distance to extension centre	**-0.0001**	**-2.64*****	**-0.0002**	**-1.78***	**0.0001**	**1.67***	**-0.0002**	**-1.37**	**-0.0001**	**-0.67**	**-0.0002**	**-1.20**
Head age	0.0436	2.09**	0.0062	0.18	0.0010	0.02	0.0040	0.11	0.0475	1.11	0.0464	1.07
Head age square	-0.0004	-1.84*	-0.0002	-0.43	-0.00003	-0.07	-0.0001	-0.23	-0.0007	-1.51	-0.0005	-1.09
Head education	0.1022	2.58**	0.1272	1.96*	-0.0030	-0.04	0.0669	0.85	0.1086	1.12	0.0706	0.80
Head education square	-0.0027	-0.86	-0.0065	-1.34	0.0012	0.21	-0.0066	-0.98	-0.0040	-0.63	-0.0034	-0.55
Household size	0.0447	2.87***	0.0375	1.55	0.0673	2.42**	0.0140	0.53	-0.0082	-0.27	0.0032	0.14
Head sex	0.0119	0.09	-0.0480	-0.24	0.4192	1.30	0.1492	0.59	0.3861	1.13	0.2654	1.04
Household tribe 1	-0.1745	-1.32	-0.5048	-2.42**	-0.5494	-2.41**	-0.0745	-0.32	-0.7806	-2.96***	-0.7130	-3.36***
Household tribe 2	-0.1961	-1.31	-0.9362	-3.37***	-0.9766	-2.82***	-0.1268	-0.48	-0.1325	-0.47	-0.7439	-2.22**
Region-Central Kampala	-0.4352	-2.76***	0.7370	2.79***	0.7039	2.56**	0.6147	2.31**	1.4872	4.10***	0.7039	3.21***
Region-East	-0.0967	-0.70	0.5637	2.28**	0.6228	2.27**	0.1946	0.75	0.2872	0.83	-0.0551	-0.24
Region-North	0.2396	1.49	1.6291	5.14***	1.0875	2.82***	0.1839	0.56	1.0845	2.94***	0.1757	0.40
Region-Kampala	-5.9067	-0.01	-3.1200	-0.01	-4.2282	-0.00	-1.7054	-0.00	1.5166	1.36	-2.7718	.
Rural/Urban	-0.0284	-0.18	0.0865	0.38	0.1885	0.56	-0.1809	-0.68	-0.1818	-0.72	0.1131	0.48
Household training	0.3562	2.27**	0.2845	1.45	0.2496	1.01	-4.0181	-0.00	0.2558	1.16	-19.8657	.
Female burden share	-0.3860	-0.97	-1.1705	-1.89*	0.8693	0.97	0.1236	0.17	1.9133	2.50**	-0.6449	-1.01
Female share	0.3993	1.08	1.0937	1.95*	-0.4547	-0.54	0.4255	0.61	-1.3097	-1.83*	1.2790	1.85*
Extension	-2.2294	-4.01***	-2.6937	-2.99***	-3.1878	-2.89***	-2.3051	-2.25**	-3.4484	-3.15***	-3.7032	-3.42***
athrho	-0.3079	-1.36	-0.2852	-1.70*	-0.2860	-1.56	1.0778	5.78***	1.4084	7.95***	1.6439	6.35***
lnsigma	-0.1978	-4.67***	-0.2099	-8.15***	-0.2139	-8.71***	-0.1797	-7.04***	-0.1708	-6.88***	-0.1686	-6.79***
N	924		924		924		924		924		924	
Rho	-0.2986		-0.2777		-0.2784		0.7924		0.8871		0.9280	
Sigma	0.8205		0.8107		0.8075		0.8356		0.8429		0.8449	
Lambda	-0.2450		-0.2251		-0.2248		0.6621		0.7478		0.7840	
LR statistics	0.84		1.24		0.98		9.88	***	30.92	***	25.33	***
Wald Chi2	135.09	***	138.32	***	140.00	***	163.88	***	225.57	***	226.98	***

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 Vulnerability in Uganda

	(i)NAADS (Government)		(ii) NGO		(iii) Cooperatives		(iv) Large farmer		(v) Input supplier		(vi) Others	
Variables	Coef.	Z value	Coef.	Z value	Coef.	Z value	Coef.	Z value	Coef.	Z value	Coef.	Z value
Impact equation												
Head age	-0.0054	-8.99***	-0.0052	-9.36***	-0.0052	-9.17***	-0.0054	-9.36***	-0.0052	-9.50***	-0.0054	-9.39***
Head age square	0.0001	10.36***	0.0001	10.72***	0.0001	10.46***	0.0001	10.65***	0.0001	10.81***	0.0001	10.66***
Head education	-0.0139	-11.48***	-0.0139	-12.39***	-0.0135	-11.95***	-0.0137	-11.98***	-0.0135	-12.42***	-0.0134	-11.77***
Head education square	0.0011	12.76***	0.0011	12.85***	0.0011	12.39***	0.0011	12.50***	0.0011	12.93***	0.0011	12.03***
Household size	0.0020	4.31***	0.0021	4.62***	0.0018	4.01***	0.0022	4.73***	0.0021	4.90***	0.0021	4.71***
Head sex	-0.0316	-8.78***	-0.0314	-8.71***	-0.0329	-8.91***	-0.0321	-8.64***	-0.0315	-8.84***	-0.0322	-8.67***
Household tribe 1	0.0228	6.09***	0.0233	6.31***	0.0251	6.66***	0.0220	5.83***	0.0219	6.01***	0.0242	6.42***
Household tribe 2	0.0026	0.61	0.0040	0.93	0.0057	1.30	0.0021	0.48	0.0020	0.48	0.0034	0.78
Region-Central Kampala	0.0115	2.45**	0.0086	1.99**	0.0065	1.49	0.0072	(1.63)a	0.0106	2.40**	0.0054	1.21
Region-East	0.0070	1.83*	0.0057	1.46	0.0048	1.21	0.0055	1.38	0.0072	1.89*	0.0054	1.36
Region-North	0.0174	3.68***	0.0138	2.76***	0.0148	3.14***	0.0182	3.85***	0.0188	4.03***	0.0177	3.75***
Region-Kampala	-0.0026	-0.11	-0.0070	-0.30	-0.0104	-0.44	-0.0090	-0.38	-0.0065	-0.27	-0.0099	-0.42
Rural/Urban	-0.0504	-10.94***	-0.0504	-10.98***	-0.0520	-11.07***	-0.0497	-10.47***	-0.0509	-11.27***	-0.0512	-10.83***
Household training	0.0525	10.68***	0.0527	11.61***	0.0530	11.52***	0.0552	11.87***	0.0544	12.04***	0.0568	12.23***
Female burden share	0.0182	1.55	0.0204	1.72*	0.0152	1.27	0.0174	1.43	0.0183	1.55	0.0236	1.95*
Female share	-0.0203	-1.82*	-0.0219	-1.96*	-0.0185	(-1.64)a	-0.0206	-1.81*	-0.0197	-1.79*	-0.0262	-2.29**
Extension	0.0111	0.74	0.0286	2.19**	0.0596	5.30***	0.0659	9.02***	-0.0093	-0.41	0.0833	13.56***
Constant	0.5503	35.35***	0.5477	36.27***	0.5498	35.64***	0.5505	35.33***	0.5473	36.88***	0.5531	35.56***
Participation equation												
Distance to extension centre	-0.0001	-2.48**	-0.0002	(-1.64)a	0.0001	2.04**	-0.0001	-0.88	0.0001	0.60	-0.0001	-1.09
Head age	0.0471	2.21**	0.0010	0.03	0.0334	0.78	0.0432	1.12	0.0852	1.32	0.0607	1.51
Head age square	-0.0004	-1.96*	-0.0001	-0.22	-0.0004	-0.93	-0.0003	-0.94	-0.0011	-1.46	-0.0006	-1.50
Head education	0.0964	2.40**	0.1362	2.07**	-0.1040	-1.28	0.0848	1.07	0.0551	0.54	0.0336	0.46
Head education square	-0.0021	-0.66	-0.0067	-1.35	0.0069	1.10	-0.0068	-1.15	-0.0014	-0.20	0.0002	0.03
Household size	0.0398	2.43**	0.0487	1.85*	0.1072	3.56***	0.0222	0.69	-0.0490	-1.08	0.0335	1.17
Head sex	-0.0202	-0.16	-0.1029	-0.50	0.2705	0.84	0.2630	0.95	0.2873	0.81	0.2626	1.09
Household tribe 1	-0.1528	-1.14	-0.5012	-2.37**	-0.4351	-1.90*	0.0034	0.02	-0.6025	-1.86*	-0.4727	-2.21**
Household tribe 2	-0.1889	-1.23	-1.1692	-3.65***	-1.1626	-2.52**	-0.0048	-0.02	-0.0306	-0.08	-0.3070	-1.09
Region-Central Kampala	-0.4592	-2.81***	0.7645	2.76***	0.9292	3.50***	1.1482	4.59***	1.5295	3.24***	1.6096	6.52***
Region-East	-0.0755	-0.54	0.6633	2.56**	0.7693	3.08***	0.8967	3.70***	0.7428	1.52	1.3333	5.65***
Region-North	0.2472	1.50	1.8744	5.27***	1.2237	2.60***	-0.4519	-1.10	1.3539	2.68***	0.2491	0.68
Region-Kampala	-6.3523	-0.00	-3.2175	-0.00	-3.9073	-0.00	-2.3743	.	2.2114	1.85*	-2.7109	.
Rural/Urban	-0.0323	-0.20	0.1143	0.48	0.2808	0.81	-0.4336	-1.56	-0.3018	-0.89	0.0635	0.22
Household training	0.3865	2.45**	0.2798	1.38	0.3781	1.68*	-4.4996	.	0.4500	1.77*	-4.2540	.
Female burden share	-0.3301	-0.77	-1.4276	-2.00**	1.8603	1.76*	-0.2240	-0.23	2.2156	1.99**	-3.6196	-4.41***
Female share	0.4608	1.11	1.5567	2.23**	-0.7645	-0.78	1.9281	1.85*	-1.4266	-1.46	4.4488	4.33***
Extension	-2.3073	-4.10***	-2.9490	-3.22***	-4.0846	-3.52***	-4.6964	-4.39***	-4.3049	-2.61***	-6.1158	-5.84***
athrho	-0.2313	-0.97	-0.4059	-2.18**	-0.8797	-4.26***	-1.4322	-7.19***	0.0742	0.26	-1.7116	-7.90***
lnsigma	-3.2673	-87.23***	-3.2632	-114.99***	-3.2421	-117.28***	-3.2321	-128.39***	-3.2805	-138.45***	-3.2340	-131.52***
N	902		902		902		902		902		902	
Rho	-0.2272		-0.3850		-0.7062		-0.8921		0.0741		-0.9369	
Sigma	0.0381		0.0383		0.0391		0.0395		0.0376		0.0394	
Lambda	-0.0087		-0.0147		-0.0276		-0.0352		0.0028		-0.0369	
LR statistics	0.95		3.47	*	10.83	***	24.37	***	0.07		37.60	***
Wald Chi2	1096.57	***	1091.85	***	1070.21	***	1102.79	***	1125.54	***	1209.31	***

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

Table 6: 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	ATT	**3.42%*** **	0.25%	**9.94%*** **	**1.96%*** **	**4.71%*** **	**-6.89%*** **
	Improve?	**Yes**	-	**Yes**	**Yes**	**Yes**	**No**
MPCE	ATT	**13.74%*** **	-1.05%	**9.75%*** **	**56.35%*** **	**57.39%*** **	**112.32%*** **
	Improve?	**Yes**	-	**Yes**	**Yes**	**Yes**	**Yes**
Vulnerability	ATT	**-0.38%* **	**-0.52%*** **	**-1.20%*** **	**-3.79%*** **	-0.15%	**-2.87%*** **
	Reduce?	**Yes**	**Yes**	**Yes**	**Yes**	-	**Yes**

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.

Table 7: Poverty and vulnerability incidence in Uganda, 2010-11

Vulnerability	Poor (<1.25 $)	Non-poor (≥1.25 $)	All
High (>0.4292)	143 (11.03)	75 (5.79)	218 (16.82)
Moderate (0.3156 – 0.4292)	674 (52.01)	187 (14.43)	861 (66.44)
Less vulnerable (<0.3156)	177 (13.66)	40 (3.09)	217 (16.74)
All	994 (76.70)	302 (23.31)	1296 (100)

Note: Figures in the parenthesis indicate respective percentage of each cell.

Appendix

Table A1. Descriptive statistics of different variables used for the estimation

Variable	Minimum	Mean	Maximum	Std.Dev.	Description
Production variables					
Land	0	9.30	601.5	21.95	Land cultivated by the household
Labor	0	273.19	9631	343.96	Labor used for cultivation
Inputs	0	35990.95	2470000	109161.9	Inputs used for cultivation
Outputs	0	2.26e+07	2.15e+09	8.27e+07	Output from products and by-products
Dependent variables for impact estimation					
te	0.00004	0.2199	0.8276	0.1998	Technical efficiency estimated by SFA with Cobb-Douglas specification
MPCE	1.37	875.10	9527.13	800.70	Mean per capita consumption expenditure
pMPCE	287.85	817.31	2013.40	262.39	Predicted mean per capita consumption expenditure
Vulnerability	0.1945	0.3724	0.4891	0.0568	Vulnerability of household
Variance _pMPCE	755.88	3584.91	45526.57	4189.35	Variance of pMPCE
Household variables					
Head age	13	44.95	100	15.24	Age of household head
Head education	0	4.79	15	4.11	Educational level of household head
Household size	1	5.94	23	3.19	Number of family members of the household
Head sex	0	0.72	1	0.45	Sex of household head 0=female, 1=male
Household tribe 1	0	0.2703	1	0.4443	Household identified under different tribes, up to score 21 provided by UNPS
Household tribe 2	0	0.3631	1	0.4811	Household identified under different tribes, score 22 to 36 provided by UNPS
Household tribe 3	0	0.3666	1	0.4820	Household identified under different tribes, more than score 36 provided by UNPS
Region-Central Kampala	0	0.1926	1	0.3945	Dummy for central region except Kampala
Region-East	0	0.2407	1	0.4277	Dummy for east region
Region-North	0	0.2620	1	0.4399	Dummy for north region
Region-Kampala	0	0.0041	1	0.0641	Dummy for Kampala region
Region-West	0	0.2992	1	0.4581	Dummy for west region
Rural/Urban	0	0.74	1	0.44	Dummy for rural area 0=urban, 1=rural
Household training	0	0.11	4	0.37	Number of household members received training
Female burden share	0	0.24	1	0.20	Share of female members within age of below 15 and above 64 to the total household members
Female share	0	0.51	1	0.23	Share of female members to the total household members

Table A2. Correlation between Instrument (distance from village centre to extension service) with Outcome Variables and Variables on Extension

Variables	Correlation coefficient
Outcome variables	
Technical efficiency	-0.0149
MPCE	-0.0267
Vulnerability	0.0723
Extension variables	
(i) NAADS	-0. 1182
(ii) NGO	-0.0604
(iii) Cooperatives	0.0725
(iv) Large farmers	-0.0370
(v) Input suppliers	0.0518
(iv) Others	-0.0257

Table A3. The Results of OLS model of household characteristics on the poverty (lnMPCE) and vulnerability in Uganda

Variables	Poverty (lnMPCE)		Vulnerability	
Head age	0.0174*	1.77	-0.0055***	-12.4
Head age square	-0.0001	-1.34	0.0001***	13.61
Head education	-0.0086	-0.44	-0.0137***	-15.5
Head education square	0.0027*	1.69	0.0011***	15.98
Household size	-0.0557***	-6.7	0.0020***	5.45
Head sex	0.0508	0.78	-0.0308***	-10.42
Household tribe 1	-0.2815***	-4.11	0.0205***	6.74
Household tribe 2	-0.0968	-1.34	-0.0038	-1.14
Region-Central Kampala	0.4390***	5.77	0.0130***	3.79
Region-East	0.1645**	2.33	0.0117***	3.7
Region-North	-0.0339	-0.42	0.0259***	6.97
Region-Kampala	0.7386**	2.02	0.0116	0.72
Rural/Urban	0.0632	0.8	-0.0502***	-14.09
Household training	0.3209***	3.94	0.0513***	14.15
Female burden share	-0.7082***	-3.5	0.0098	1.02
Female share	0.5141**	2.69	-0.0106	-1.15
Constant	6.0455***	23.25	0.5527***	47.03
N	1339		1296	
R squared	0.1151		0.5577	
F statistics	10.74***	(16, 1322)	0.5577***	(16, 1279)

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