Explaining the Adoption of Improved Maize Varieties and its Effects on Yields among Smallholder Maize Farmers in Eastern and Central Uganda

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Abstract: The study analyzes adoption of improved maize varieties and its effects on farm yields and rural poverty using cross sectional data collected from 151 households in central (in Nakasongola district) and Eastern (in Soroti district) regions in Uganda. A binary probit model was fitted to examine the determinants of level of adoption. OLS method was used to estimate the determinants of intensity of adoption and the effect of adoption on yield. The sample statistics show very high levels of adoption (about 80%) and a low level of adoption intensity. The mean yields from improved maize varieties (2941.5kg/ha per season) is significantly higher than the yields from local varieties (1694. kg/ha per season). Regression results show that extension advisory services are strongly associated with adoption of improved varieties. Intensity of adoption of improved maize varieties increases farm yields. However, maize yields respond inelastically to adoption. We conclude that adoption of improved seed leads to increased yield. Thus more technical assistance in the form of training and extension is justified in the country on efficiency and welfare grounds.

Key words: Adoption · Improved maize varieties · Yield

INTRODUCTION

Like other developing countries, Uganda has, over the years, embraced the ideology of green revolution as a strategy to improve productivity and fight poverty and food insecurity. Agricultural research and development is one of the key pillars of Plan for Modernisation of Agriculture the (PMA), a key pillar of the Government's comprehensive development framework, the Poverty Eradication Action Plan (PEAP). The national research and development policy framework promotes the generation and development of high quality and efficient agricultural research technologies. Maize is one of the major staple crop enterprises in Uganda that have been targeted for research and development over the last two decades.

Being a major staple food crop across all regions of Uganda, maize production has been the target of support from both government and non-governmental organizations. Maize production has been actively promoted by several programs and organizations such as Sasakawa-Global, 2000 as a package of improved seeds and fertilizer which has caused its expansion to all zones of Uganda [1]. Over the past three decades, an average land area of 384,000 hectares has been allocated to maize; and production has averaged 522,000 metric tons with a grain yield of 1.3 ton per hectare [2]. The overall trend of production, area and yield during this period shows that yield has stagnated or declined and the growth in maize production has primarily been due to area expansion. As such several improved varieties including *Longe series, hybrids,* have been generated and disseminated to farmers through the various Technology Uptake Pathways (TUPs)[1] country wide.

The major interest of agricultural researchers, development partners, policy makers and other agribusiness stakeholders is to understand how and

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[1]There are many TUPs in Uganda including Community Based Organization, Farmer Research Organization, NGOs, private companies(seed companies, input dealers), National Agricultural Advisory services, Zonal Agricultural research and Development institutes etc that disseminate refined and adapted technologies, including improved maize varieties, to farmers in Uganda. The TUPs use various approaches of dissemination such as farmer Field Schools, Demonstration trials and plots, workshops and seminars, farmer exchange visits.

when new technologies are used by the farmers and the benefits they offer to the farmers [3]. Past adoption studies conducted in Uganda mainly focused on adoption rates paying little attention, if any, to adoption intensity and on the effects of adoption on farmer's welfare [4,5]. The present paper explains adoption intensity of improved varieties and its effect on yield. The specific objectives of the study are to: (i) estimate the level and intensity of adoption of improved maize seed, and (ii) assess the effects of the new maize varieties on maize yield. The study is based on the premise that adoption of improved agricultural innovations enhances farmers' welfare through increased farm productivity.

MATERIALS AND METHODS

Study Area, Sample and Survey Methods: This study utilizes cross-sectional primary data collected using a questionnaire that was administered through direct interviews to maize farmers in the central and eastern regions of Uganda. A multi stage sampling procedure involving a combination of purposive and simple random sampling methods was used to select the study locations as well as the sample farmers. Maize farmers were selected from Nakasongola and Soroti districts in central and eastern regions of Uganda, respectively. A random sample of 151 farmers was selected including 73 from central region and 78 from eastern region.

Econometric Estimations
The Theoretical Model: The study adopted a household farm production model along the lines of those discussed by [6], in which the household engages in agricultural production as well as the production of health, nutrition, productivity and children.

$$U = f(Y,W,N) \qquad (1)$$

where; Y is yield from household's farm; W is non-farm products from which a household derives utility. The household's yield function is specified as:

$$U=f(Z,X,u) \qquad (2)$$

where; X is a vector of control variables including household characteristics such as sex, education, age. Z is improved inputs. In order to maximize utility, households strive to maximize farm yield (equation 2) subject to a budget constraint. The budget constraint is simply an expression of the total resources available to

the household and a description of how they can be spent (equation 3)

$$I=ZP \qquad (3)$$

where; I is the exogenous household income allocated to input purchasing and P is the price of the improved input used in production. Equations 1-3 can be solved to derive the input demand function of the form

$$Z=f(P,I,u) \qquad (4)$$

Price of input affects farm demand for the input without directly affecting the farm yield. It was assumed that farmers decide to use or not to use improved inputs before making any decisions regarding the quantity of input to use in a given area. The decision to adopt is also influenced by institutional variables such as information access. Hence, equation 2 can also be extended to capture the effect of information access on the farmer's decision to adopt the new technology. Therefore a double hurdle approach can be applied using two-step Heckman's procedure. In the research, the first component of the selection model is the probit to empirically predicting farmers' participation in the input market. The demand for improved inputs is specified as:

$$Z=f(P,I,E_X,u) \qquad (5)$$

The effect of changes in input prices on the yield can be derived from equation 2 and the change in yield can be expressed as.

$$\partial Y=F_Z\partial Z+F_X,u \qquad (6)$$

where; F_z and F_u are the marginal products of the inputs Z and u, respectively used to produce Y. From equation 6, the change in farm yield can be related to changes in prices of the improved inputs used in production as follows:

$$\frac{\partial Y}{\partial P}=F_z\frac{\partial Z}{\partial P}+F_\mu\frac{\partial u}{\partial P} \qquad (7)$$

where; $\frac{\partial \mu}{\partial P}=0$ so that in equation 7, the terms $F_\mu x$ (.)=0, since u is the random variable uncorrelated to commodity prices. Equation 7 shows that input prices are correlated with farm yield. The signs and sizes of the effects of input prices on yield depends on (a) the magnitude of changes in the demand for the inputs following the changes in prices and (b) size of the marginal products of the inputs.

Model Estimation: Since household utility U is unobserved, the parameters of the household yield function (equation 2) are not identified. Equations 3 suggest the identifying instruments, the exclusion restrictions. The instruments for the present paper include prices of maize seed. Income was excluded from the instrument set because it correlated with price. The random yield endowment was excluded because it was correlated with both yield and input demand. Equation 2 was estimated using a maximum likelihood method that allows for correction of structural parameters for biases due to endogeneity of input and censoring and heterogeneity of the yield. The control function approach [6] is used deal with the bias due to non-linear interaction of inputs into yield with unobservable variables specific to individual; households. Following Wooldridge [7], the yield function was estimated using the approach below:

$$y = k_1\delta_y + \Sigma\beta_z + \varepsilon_1 \qquad (6)$$

$$z = k_2\delta_z + \varepsilon_2 \qquad (7)$$

where;

y and z represent, respectively, yield and endogenous regressors. The term k_1 is a vector of exogenous variables; k is an exogenous set of variables comprising k_1

variables that belong in the yield equation, plus a vector of instruments, k_2 that affect only the endogenous technological maize inputs, z, without directly influencing the yield, *y*; δ, β are vectors of parameters to be estimated; and ε is the disturbance term. During estimation, maize inputs are treated as a single package of new seeds so that the summation symbol in equation (6) is omitted. Dummy for region was introduced to capture the location specific attributes. Elasticity estimates were generated from the estimation results.

RESULTS AND DISCUSSION

Descriptive Statistics
Summary Statistics of the Variables Used in the Model: The descriptive statistics for the sampled characteristics including all the variables used in the models are presented in Table 1. The results from the survey show high adoption rates (about 80%) for the improved maize in both study areas. This implies that over three quarters of the sampled maize farmers grew improved varieties. High adoption rates can be attributed to the highly successful campaign at developing and disseminating improved maize varieties especially the popular *Longe* series of maize. Higher adoption rates were observed in Nakasongola relative Soroti.

Table 1: Summary statistics of the variables used in the model

|	Pooled sample	Nakasongola (central)	Soroti (eastern)
Level of adoption (1 if yes; 0 otherwise)	0.84 (0.37)	0.89 (0.32)	0.79 (0.41)
Proportion of maize acreage under improved variety	0.24 0.23)	0.22(0.26)	0.26(0.19)
Seeding rate (Kg/ha)			
Pooled	39.70 (32.80)	30.89 (19.06)	47.86 (40.49)
Improved varieties	41.6 (34.5)	31.01(18.04)	52.56 (43.62)
Local varieties	31.6(20.4	33.80 (25.65)	30.56 (18.04)
Price of maize seed (Uganda shillings/kg)			
Improved seed	587.40 (280.15)	636.49 (327.70)	539.13 (215.91)
Local seed	279.4 (61.0)	287.4 (27.3)	275.9 (71.5)
Square of price of maize seed (Uganda shillings/kg)	278891.7 (516103.7)	367533.1 (621238.8)	197068.9(381360.8)
Yield (kg/ha):			
Improved varieties	2941.5 (2626.4)	2897.60 (2450.56)	2997.05(2845.32)
Local varieties	1694.5 (1506.3	1835.76(1802.31)	1623.81(1395.37)
Farmer's experience in maize production	4.8 (2.5)	4.7 (2.6)	4.8 (2.5)
Square of farmer's experience in maize production	32289.0 (359207.8)	65606.3 (512143.3)	29.4 (29.9)
Membership to farmer group (1 if yes; 0 otherwise)			
Pooled	0.432 (0.497)	0.507(0.504)	0.364(0.484)
Adopters	0.462 (0.501)	0.533(0.503)	0.390 (0.492)
Non-adopters	0.308 (0.471)	0.375 (0.518)	0.278 (0.461)
Farming risks (years of crop failure)	3.8 (2.3)	4.8 (2.8)	3.0 (1.4)
Square of farming risks (years of crop failure)	19.4 (25.8)	30.2 (34.2)	10.6 (9.9)
Extension (visits received per season)			
Pooled	4.51(3.72)	4.98 (3.87)	3.48 (3.22)
Adopters	2.62 (3.65)	5.16 (3.95)	3.48(3.22)
Non-adopters	0.38 (0.98)	2.50 (1.00)	na
Square of Extension (visits received per season)	34.1(59.1)	39.5 (65.3)	22.0 (41.1)
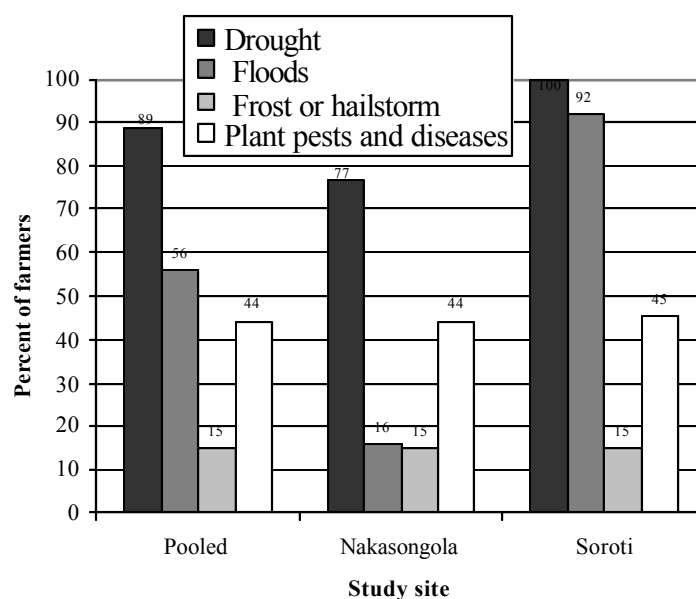
Fig. 1: Major factors faced by the farmers
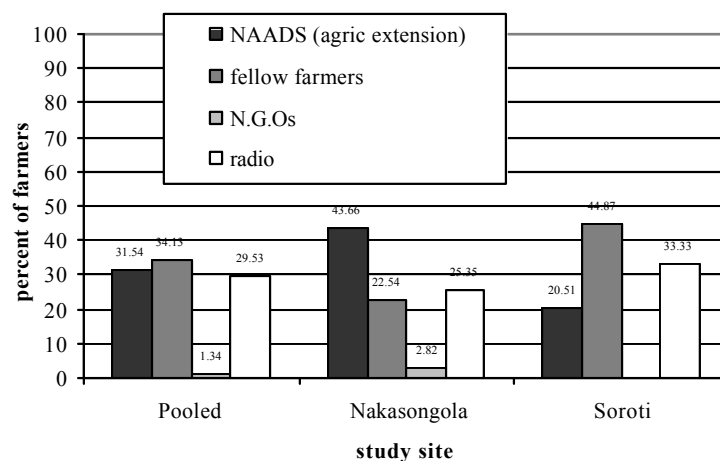
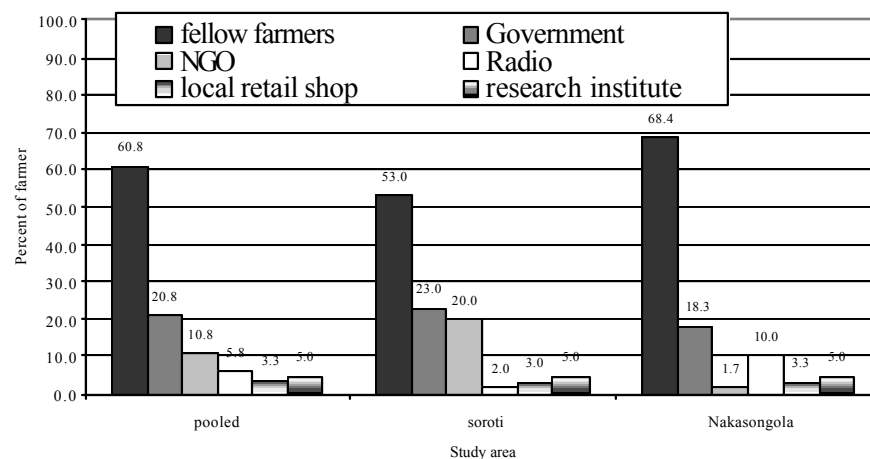Fig. 2: Source of extension and advisory services

Fig. 3: Farmer's source of information on the use of improved seed

Although the majority of interviewed maize farmers grew improved varieties, the intensity of adoption of the varieties is still low. Results show an average adoption intensity of about 22%. An average maize farmer in soroti and Nakasongola, respectively, planted about 26% and 24% of their farm acreage with improved maize seeds. The maize yield from improved varieties (2.942 kg/ha) were higher than the 169 4kg/ha realized from traditional varieties. It can also be noted from the results that maize yield was comparable across the study areas. The reported farm level yields are, however, still far below the potential yield of 5-8MT/ha [8]. This gap is attributed to several factors, including the recycling of improved seeds and limited use of yield-enhancing inputs and practices, such as fertilizers, crop rotation and land fallowing as well as other risks associated with crop production. The average price of improved maize seed was 587.4 Uganda shillings per kg. The seed was mainly obtained from local markets, local input dealers and own saved seed, on average.

The results further show higher farming risks among farmers in Nakasongola (about 5 years) relative to the 3 years reported in Soroti. The risk was measured as the number of years of crop failure experienced by the farmer in the last 10 years. The major risk factors reported in Nakasongola include drought (as reported by 77%) and plant pests and diseases (by 44%) while sampled farmers in Soroti reported drought (100%), floods (reported by 92%) and pests and diseases (45%) as the main causes of crop failure (Fig. 1).

Access to agricultural extension services and advisory services, necessary precursor to technology adoption, was proxied by the number of extension visits received by the household. As can be discerned from Table 1, an average household received about 5 visits from extension agents. The level of interaction with extension agents was higher in Nakasongola (5 visits) than Soroti (3 visits). It is also noticeably clear from the results that adopters in all study sites had more interactions with the extension agents compared to their non-adopting counterparts (Table 1). The main sources of agricultural advisory and extension are the National Agricultural Advisory Services (NAADS) (43% in Nakasongola and 20% in Soroti) and fellow contact farmer (44% Soroti and 22% for Nakasongola) (Fig. 2).

Improved Maize Varieties Grown, the Desired Attributes and Seed Source: The most common varieties planted in Soroti were *Longe* 1 (reported by

48%) followed by *Longe* 5 (32%) and *Longe* 4 (by 20%). On the other hand, *Longe* series 5 and 4 were the dominant varieties planted in Nakasongola (as reported by 43% and 41% of the adopters). The varieties are preferred by the farmers because they are resistant to drought (86%), early maturing (reported by 83%) and high yielding (78%). Others attributes include resistance to pest and diseases, large cob size, resistance to lodging, large grains and more cobs per plant (Table 2).

Improved maize seed was mainly sourced from local input supply shops (reported by 83% of farmers in Nakasongola and 30% for Soroti), government departments such as local government and NAADS (as indicated by 64.7% in Nakasongola and 23 % of farmers in Soroti). Other seed sources include NGOs and local markets as well as own saved seed from previous season (Table 2). Information on use of improved seed was mainly acquired from fellow farmers (reported by 64.8% of farmers in Nakasongola and 53% for Soroti), NAADS (as indicated by 23% of farmers in Soroti and 18% in Nakasongola). Other sources of information include local radio programmes on agriculture, NGOs operating in the area, local input suppliers and staff from research institutions (Fig. 3).

Econometric Results
Factors Affecting Intensity of Adoption of Drought Tolerant Maize in Uganda: Table 3 presents estimates of OLS regression for the determinants of intensity of adoption of improved maize in the study districts. As can be discerned from the results, farm demand for improved seed is significantly influenced by household utilization of extension and advisory services and risks associated with farming. Results show that intensity of adoption first decreases, then increases with more extension visits, suggesting that increased interaction of the farmer with extension service providers increases their awareness and knowledge regarding the use of improved technologies. Extension is a form of human capital and households endowed with such capital are likely to have greater farm management capacity or ability to understand and use new technologies. The results underscore the important role played by extension agents in increasing diffusion of improved maize technologies in the country. It should be noted that the response of adoption to extension is quite slow. The elasticity estimate for the square of extension is only 0.02 (in col. 2b Table 3) indicating that a 10% increase in

Table 2: Improved maize varieties adopted by farmers and their desired attributes

	Pooled (n=120)		Soroti (n=60)		Nakasonogola (n=60)	
Adopted varieties	Freq.	Percent	Freq.	Percent	Freq.	Percent
Longe 5	45	38	19	32	26	43
Longe 1	22	18	29	48	9	15
Longe 4	36	30	12	20	25	42
Desired attributes						
High yield potential/more cobs per plant	113	95	65	108	48	80
Early maturity	99	83	57	95	42	70
Drought resistance	86	72	44	73	44	73
Pest/disease resistance	21	18	5	8.3	16	27
Large cob size	39	33	20	33	19	32
Large grains/heavy grains	26	22	13	22	13	22
Resistance to lodging	9	7.5	5	8.3	2	3.3
Tasty green maize	15	13	4	6.7	11	18
Source of seed						
Agro-input-dealer	47	39	18	30	50	83
Local market	17	14	7	12	20	33
Non-government Organization	23	19	19	13	22	37
Farmer	22	18	10	8	14	23
Government/Ministry of Agriculture	19	16	15	23	39	64
Own saved from previous season	12	10	5	8	14	23

Table 3: Effect of extension on intensity of adoption of improved seed

Variable	Coefficient (2a)	Elasticity(2b)
Farming risks (years of crop failure)	-0.082** (2.38)	-1.2706
Square of farming risks (years of crop failure)	0.009** (2.24)	0.7501
Price of maize seed X10^{-5} (Uganda shillings/kg)	-1.79 (0.17)	-0.0020
District (1=Central; 0=Eastern)	-0.0163708 (0.45)	-0.0319
Extension (visits received per season)	-0.019** (1.88)	-0.1999
Square of extension visits received per season	0.0002556 (0.36)	0.0217
Constant	0.4206207*** (5.98)	-1.2706
R-square	0.15	na
No. of observations	117	na
F-value /Wald chi-squared (*p-value*)	3.43 (0.0039)	na

Note: In parenthesis are the absolute values of t-statistics

Table 4: Effects of intensity of adoption on yield

	IV-2SLS			Control Function approach		
Variables	Yield Eqn (OLS)	First Stage Regression (Adoption Eqn)	Second Stage Regression (Yield Eqn)	Elasticity	Coefficient	Elasticity
A. *Potentially endogenous variable*	Coefficient (2a)	(2a)	(2b)	(2c)	(2a)	(2b)
Adoption of improved maiz variety (1=yes; 0 otherwise)	-0.597 (1.5)	…	2.514(1.1)	0.080	2.515 (1.69)	0.080
B. *Exogenous covariates*						
Seed rate (Kg/ha) X10^{-3}	11.4 (3.71)	-0.77(1.3)	13.8 (3.1)	0.076	15.0 (4.19)	0.076
Land size (Ha)	0.167 (1.29)	-0.1237821 (3.2)	0.605 (1.6)	0.121	0.605(2.42)	0.121
Extension visits X 10^{-4}	0.135 (0.00)	-110 (0.7)	276 (0.4)	0.010	270(0.54)	0.001
Square of extension X 10^{-4}	- 19.1 (0.67)	1.81 (0.1)	-19.0 (0.5)	-0.005	-20.0 (0.67)	-0.005
Region (1=central; 0=Easternl)	0.253 (1.46)	-3.29e-3 (1.6)	0.118 (0.4)	0.008	0.118(0.69)	0.008
C. *Instruments for improved seed Adoption*						
Price of maize seed x 10^{-7} (Ug.shs/Kg)		2.26 (1.7)	…			
Square of price of maize seed x 10^{-2} (Ug.shs/Kg)		3.90 (0.8)	…			
Constant	6.93(20.24)	0.543 (7.3)	5.410 (4.6)		5.410(6.58)	
R^2	0.22	0.19	…		0.24	
F-value /Wald chi-square statistics	7.80 (0.000)	3.72 (0.0012)	3.75 (0.0020)		7.06 (0.000)	
Number of observations	1170	117	117		117	
Residuals of adoption intensity					-3.196 (2.1)	1.51E-10

the number of extension visits raises the probability of adoption by 0.2%. Similarly, the demand for improved varieties (intensity of adoption) is negatively correlated with farm risk, but positively correlated with the square of farm risk. The results suggest that farmers adapt to farming risks as they encounter more episodes of crop failure. Drought is the main risk factor to farmers in the study areas. Small scale irrigation schemes that suit the small scale farmer need to be devised and promoted. Promotion of soil conservation practices that maintain soil moisture should be upheld. Price of seed is not significant but shows a negative effect on demand for improved seed, which is in line with the law of demand.

Effects of Adoption on Maize Yields: Several approaches were used to estimate structural models to establish the effect of adoption on farm yields. The IV-probit procedure [9] was used to account for endogeneity of extension in the adoption equation, while the control function approach [10] was used to account for heterogeneity of yields among farmers. The OLS approaches shows that improved maize seed is negatively associated with yield, but a positive and significant relationship is derived with IV approach. The coefficient on adoption in the yield equation derived from the OLS is -0.597 compared with an IV estimate of 2.51. The details of results are in Table 4. The Durbin-Wu-Hausman test shows that adoption intensity is endogenous to yield, suggesting that the control function approach is the proper estimation method. The estimation results derived using the control function approach (columns 3a of table 4) also show that adoption increases yields. The results, however, demonstrate that yields respond slowly to adoption as the elasticity is only 0.08. However, control function estimation results did not show any heterogeneity in yields among farmers; the results are not reported.

The positive and significant relationship between adoption of improved seed and maize yield is line with the Uganda Plan for Modernization of Agriculture's objective of poverty eradication through improved household productivity and profitability. The findings underscore need to design strong technology transfer and diffusion processes that will sustainably increase technology adoption among the smallholder farmers. Other important determinants of yields (apart from the adoption of new seeds) include quantity of seed planted per hectare and land size.

CONCLUSIONS AND RECOMMENDATIONS

The results show high level (about 80%) of adoption but low intensity of adoption (22%) of improved maize varieties. They further show significantly higher mean yields from improved maize varieties (2.942 kg/ha per season) compared to the local varieties (1694 kg/ha per season). The reported yield is however less that one fifth of the expected yield. The yield gap can be attributed to recycling of seed of improved maize and to limited use of yield-enhancing inputs as well as other risks associated with crop production. Econometric results show household utilization of extension services increases demand for improved seed, which in turn increase farm yields. Extension education and advisory services were found to be a critical factor for increased adoption. Farmer's decision to adopt has an inelastic response to extension supply. Intensity of adoption of improved varieties significantly increases farm yield. However, maize yield exhibits an inelastic response to the level of adoption of improved maize varieties. The fact that increase in extension visits increases in the demand for the improved varieties and that increases in level of adoption increase yield, underscores the need to enhance dissemination of improved agricultural technologies. The results highlight the need for multifaceted interventions to enhance household access to extension services and advisory services in order to increase agricultural productivity and contribute to rural development.

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