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Full Length Research Paper

Determinants of improved maize seed and fertilizer adoption in Kenya

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The study quantifies factors affecting adoption of improved maize varieties and fertilizer by households in maize growing zones of Kenya. It uses Heckman two-stage model to analyze data collected from 1850 households in 2002. Credit was important in explaining the adoption of improved maize seed and fertilizer. Likewise the ability to access hired labour was positively associated with adoption of improved maize varieties and fertilizer. Education of household head and number of extension contacts played a role in the adoption of improved maize varieties. Distance to market was negatively associated with adoption of fertilizer. Use of fertilizer affected the adoption of improved maize varieties and the converse was true. The area planted to improved maize varieties was positively affected by household characteristics (education and age of household head), institutional factors (number of extension contacts) and other variables such as ability to hire labour. Use of fertilizer was strongly and positively associated with the intensity of use of improved maize. These findings suggest that provision of credit and strengthening of research/extension farmers linkages are likely to play a significant role in enhancing the use of improved maize seed and fertilizer and therefore increasing maize productivity in Kenya.

Key words: Adoption, fertilizer, households, Heckman, Kenya, maize, seed.

INTRODUCTION

Agriculture continues to be important for sustainable development, poverty reduction and enhanced food security in developing countries (World Bank, 2008). Agriculture is a strong option for spurring growth, overcoming poverty and enhancing food security in Africa. However, agricultural productivity in Africa has continued to decline over the last decades and poverty levels have increased. In Kenya poverty has worsened consistently over the past two decades, despite the antipoverty measures by the government and international development agencies (Odhiambo and Manda, 2003). It is estimated that over 60% of the Kenyan population is estimated to be below the poverty line, with the majority of the poor residing in rural areas, where agriculture is the main source of livelihood. Lack of progress in poverty reduction is partly due to inadequate implementation of previous anti-poverty measures and partly because the measures paid insufficient attention to the development of agriculture, the backbone of the Kenyan economy. In particular, transfer of new technologies to farmers may have suffered due to under-financing of the national agricultural extension system (Bindlish and Evenson, 1997) Low agricultural productivity and poor marketing of farm produce are some of the causes of rural poverty. Low productivity is attributed to the use of traditional farming methods, poor soil fertility, unpredictable weather, high costs of inputs, and poor quality of seed and lack of credit facilities. These multiple setbacks have led to food shortages, underdevelopment of farms, low farm incomes, and poor nutritional status, especially among children, increasing further the population's vulnerability to poverty in the future.

Escaping poverty therefore depends on the growth and development of the agricultural sector. Achieving agricultural productivity growth and development will not

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be possible without yield enhancing technical options because it is no longer possible to meet the needs of increasing numbers of people by expanding areas under cultivation. Agricultural research and technological improvements are therefore crucial to increase agricultural productivity and thereby reduce poverty and meet demands for food without irreversible degradation of the natural resource base. Efforts have therefore been made to promote productivity enhancing technologies such as inorganic fertilizers and improved seed. The main objective of such development research is to reduce hunger, malnutrition, and poverty, and increase the incomes of farmers.

Maize is a major staple food in Kenya. However, despite the tremendous maize production potential exhibited between 1964 to 1975, through the introduction of maize hybrids and related technologies, often dubbed "Kenya's Green Revolution" (Karanja et al., 2003), domestic maize demand outstrips production in six out of ten years. Evidence from recent years (De Groote et al., 2011) indicates that average yields have stagnated at below 2 tons, while area per hectare has remained at about 1.5 million hectares. Given the limited arable land area and low irrigation development capacity, there is no doubt that Kenya will have to rely relatively more on yield improvement than area expansion for future increases in maize production. Use of modern varieties and inorganic fertilizer are key inputs in enhancing productivity of maize in Kenya. In their recent analysis (De Groote et al., 2005) of maize production in Kenya, adoption of improved maize and inorganic fertilizer was shown to have increased. However, small-holder farmers apply inorganic fertilizer below the recommended rates and this is attributed to high cost of fertilizer.

Technology adoption decisions in developing countries have been extensively analyzed (Feder et al., 1985). Complementing the large amount of theoretical work that focuses adoption in general, numerous empirical case studies provide rich information about the factors affecting farm-level decision to adopt hybrid maize (Byerlee, 1994; Heisey and Mwangi, 1993). The common theme emerging from this literature is that the decision to adopt hybrid maize is influenced by a complex set of factors. Depending on the context, these can include demographic characteristics of the household (size, age of household head and gender composition, wealth, education level of the household head), the expected profitability and/or perceived risk of the technology, farmers' consumption preferences, and the availability and cost of inputs, especially seed. A number of maize adoption studies in Kenya (Doss, 2003; Doss et al., 2003) provide insights on factors affecting adoption of modern maize varieties. Although useful lessons and recommendations can be made from such site specific studies, more meaningful conclusions can arrived at through data collected in diverse maize growing zones in Kenya. This paper is based on in-depth and broad based studies in maize growing ecologies of Kenya.

METHODOLOGY

Description of study area

A study by CIMMYT and KARI defined six major maize ecologies in Kenya (Hassan et al., 1998b). Moving from East to West, we first find the lowland tropics (LT) on the Indian Ocean coast, followed by the dry mid-altitudes (DM) dry transitional (DT) zones southeast of Nairobi (Figure 1). These three zones are characterized by low yields (less than 1.5 t/ha); although they cover 29% of maize area in Kenya, they only produce 11% of the country's maize (Table 2). In Central and Western Kenya, we find the highland tropics (HT), bordered on the west and east by the Moist transitional (MT) zone (transitional between mid-altitudes and highlands). These zones are characterized by high yields (more than 2.5 t/ha) and produce 80% of the maize in Kenya on 30% of the area (Table 2). Finally, around Lake Victoria, we find the moist Mid-altitude (MM) zone, which produces moderate yields (1.44 t/ha), covers 22% of the area and produces 9% of maize in the country.

Sampling framework

A two stage stratified sampling design with agro-ecological zones as strata was used to select a representative sample of 1850 maize farmers in 16 sublocations across six maize growing zones (Table 1). The administrative unit "sub-location" formed the first stage, of which 10 to 20 units were selected in proportion to size, and from each sub-location 10 to 20 farmers were selected. Data were collected on farmer and farm characteristics, their knowledge of and access to modern varieties and chemical fertilizers, access to credit and extension through personal interviews using structured questionnaire. Social Package for Social Sciences (SPSS) version 15 and STATA version 7 Econometric Software were used for data analysis.

Adoption model

Feder et al. (1985) defines adoption as the degree to which a new technology is used in long-run equilibrium when farmers have complete information about the technology and it's potential. Therefore, adoption at the farm level indicates technology in the production process. The commonly used procedure to assess adoption at the farm level is a binary variable (adoption of improved maize seed = 1, non-adoption = 0). The intensity of adoption is analyzed using a continuous dependent variable (e.g., hectares under improved maize varieties). Most of the technical agricultural innovations are in the form of a technology package. The choice to adopt a technical component entails adoption of one or more of the complementary components. Adoption of several components will require the estimation of two or more adoption equations. The econometric procedure then depends on the assumption about the adoption process (Kaliba et al., 2000). Decisions to adopt improved maize seed and fertilizer are often made simultaneously (Doss and Morris, 2001; Kaliba et al., 2000; Nkonya et al., 1997; Smale et al., 1994). The two adoption decisions are linked and therefore if these factors are included as independent variables, a non-zero covariance between the disturbance term and the independent variable exists. In order to correct for the simultaneity bias, the adoption equations have to be solved using the two-stage estimation procedure (Amemiya, 1979; Nelson and Olson, 1978). In this study we specify the two adoption decisions as follows:

$$P(IMV) = f(AEZ, SEX, HLB, EDUHH, AGEHH, EXT, MKT, FERT, U_i) \quad (1)$$

$$P(FERT) = f(AEZ, SEX, HLB, EDUCHH, AGEHH, EXT, MKT, IMV, U_i) \quad (2)$$

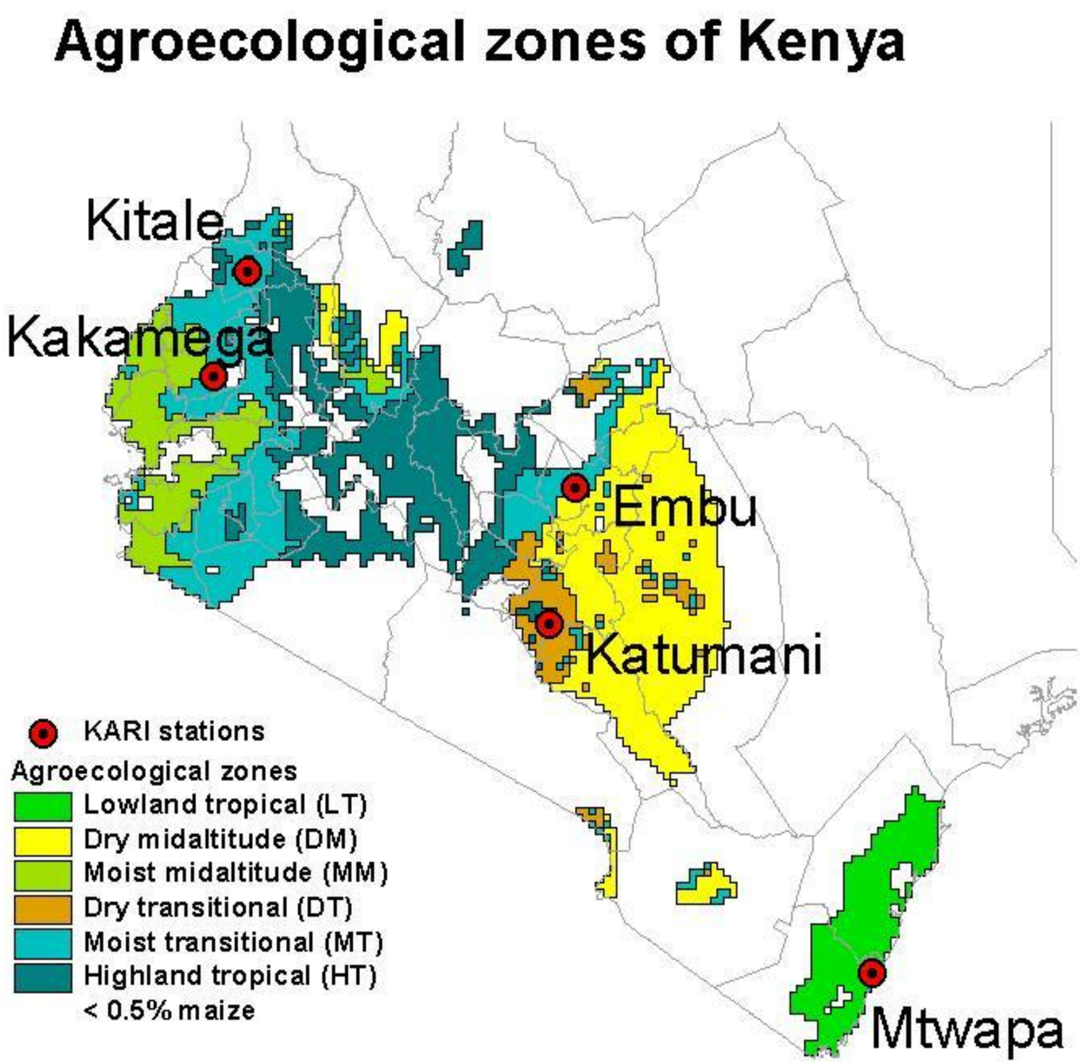

Figure 1. Major maize growing zones in Kenya.

Where: P (IMV) = probability of adoption of improved maize seed; P (FERT) = probability of adoption of fertilizer; MT = Moist Transitional Zone, 1=If farmer is in MT, 0 otherwise; LT =Low Tropics, 1=If farmers is in Low Tropics, 0 otherwise; DTZ =Dry Transitional Zone, 1=If farmer is in Dry Transitional Zone, 0 otherwise; HT = High Tropics 1=If farmer is in High Tropics, 0 otherwise; DM = Dry Mid-altitude, 1=If farmer is in dry mid-altitude zone, 0 otherwise; IMV=Use of Improved Maize Varieties, 1= if farmer uses improved maize seed, 0 otherwise; FERT= Use of fertilizer, 1= if farmer uses chemical fertilizer, 0 otherwise; SEX = Sex, 1 if household head is female, 0 otherwise; HLB = Hired labour, 1= if household is able to hire labour, 0 otherwise; EDUC = Level of education of family head (number of years); EXT = Number of extension contacts with extension provider (number in 2001); MKT=Distance to input market (km); Ui = Random error term.

In step 2, the intensity of adopting fertilizer or improved maize seed is estimated as follows:

(yi|yi>0) = xi + f (xi)/F (xi)

Where y_i = intensity of adoption of a technology (proportion of maize area planted to improved maize varieties or level/intensity of fertilizer use), xith = independent variable as specified in Equations 4 and 5.

The ratio f (bxi)/F (bxi) is the Inverse Mills Ratio (IMR), evaluated at each sample observation. IMR is calculated from the probit results of the first step. Using the data from adopters only, an Ordinary Least Squares (OLS) model, including the IMR as regressor, is estimated for each endogenous variable. The impacts of the same factors on intensity of adoption (ASHARE /X and NRATE /X) are estimated using a system of Seemingly Unrelated Regression (SUR) equations. In our case, the following two OLS equations were estimated simultaneously in a system of equations (Nkonya et al., 1998)

ASHARE = f (AEZ, SEX, HLB, EDU, AGEHH, EXT, MKT, FERT, IMR_1, U_i) (4)

NRATE = f (AEZ, SEX, HLB, EDUCHH, AGEHH, EXT, MKT, IMV, IMR_2,U_i) (5)

Overall, the factors that affect a household's decision to use a new technology such as modern maize varieties and fertilizers fall into three broad categories: market price and economic profitability-level

Table 1. Number of farmers interviewed by Maize growing zones.

Maize growing zone	Maize area(1992)[a] 1000 ha	Population (1999)[b] 1000	No interview	Interviewed (%)
Low tropics	42	1,987	300	16
Dry mid-altitude	166	2,342	200	11
Dry transitional	66	1,304	100	5
Moist transitional	466	7,537	600	32
High tropics	316	3,812	400	22
Moist Mid-altitude	173	3,018	250	14
Total	1,244	20,000	1,850	100

Source; IRMA survey 2002/2003 [a]Hassan (1998), [b]Central Bureau of Statistics (2001), unpublished data.

Table 2. List of independent variables used in the models along with their units and signs.

Variable	Unit	Hypothesized sign
Agro ecological zone		
Low tropics	Dummy (1 = If farmers is in low tropics, 0,otherwise)	+
Dry midaltitude	Dummy, (1 = If farmer is in dry midaltude zone, 0, otherwise)	+
Dry transitional zone	Dummy (1 = If farmer is in dry transitional zone, 0, otherwise)	+
Moist transitional zone	Dummy (1 = If farmers is in Moist transitional zone, 0, otherwise,	+
High tropics	Dummy, (1 = If farmer is in high tropics, 0 otherwise	+
Household head		
Sex	Dummy (1 = female;0 = male)	-
Education	Years of formal school completed	+
Age	Years	-/+
Institutional		
Hired labour	Dummy (1 = yes; 0 = no)	+
Access credit	Dummy (1 = yes; 0 = no)	+
Extension visits	Number of visits in 2001	+
Distance to input market	kilometer	_

variables, household level variables, and physical and geographical-level variables. In this paper several factors are hypothesized to influence the adoption of modern maize varieties and chemical fertilizer. A list of the independent variables used in the models along with their units and hypothesized signs is given in Table 2. One of the AEZs, Dry Midaltitude zone is used as reference and is not included in the model to avoid the problem of multicollinearity.

Several characteristics of the head of the household are included as covariates. Gender of the head of the household is represented by a dummy variable. The age of the household head is also included, as is the education of the household head (expressed as the number of years of formal schooling completed). The level of farmer’s education is hypothesized to be positively related with the adoption of modern maize varieties as it provides an opportunity to the individual to acquire knowledge about new technologies. Included also are several other explanatory variables thought to affect technology adoption decisions Since agricultural extension agents serve as an important source of technical information and improved input access, the number of extension visits is expected to be positively correlated with adoption. Similarly access to credit and the ability to hire labour are positively associated with the likelihood of adoption as is the information on agricultural technologies received through the radio. It is also hypothesized that with increasing age a farmer will be less likely to be aware of new maize varieties or fertilizer use. Younger farmers may have greater access to information because they have greater access to education, and thus will be more aware of technologies. Older farmers might not have access to this information. Distance to input markets hypothesized to be negatively related to the adoption of improved varieties. Agro ecological zone is also identified as a key variable in the adoption of improved maize seed and fertilizer. One of the zone, the dry mid-altitude zone, is not included to avoid the problem of multicollinearity.

RESULTS AND DISCUSSION

The descriptive statistics of the key socioeconomic variables used in the adoption decision are indicated in Table 3. There were more male headed households in the sample. This is typical of the household’s distribution in Kenya. The results in Table 4 show relatively higher

Table 3. Selected characteristics of households in maize growing zones of Kenya.

Characteristics	Low tropics	Dry midaltitude	Dry transitional	Moist transitional zone	High tropics	Moist midaltitude	Total
Female headed (%)	22	11.5	18	16.5	30.3	9.6	19
Hired labour (%)	43	39	49	48.2	63.8	30.8	47.4
Used credit (%)	15	12	14	38	37	20.8	27.6
Mean education of household head (years)	5.7	6.2	6.9	7.3	9	7.6	7.3
Mean age of household head (years)	48.4	49.9	55.3	48.2	54.7	48.1	50.2
Mean extension contacts in 2001	3.7	0.4	2.1	1.1	1.5	1	1.5
Mean distance to input market (km)	10.9	7.9	3.9	4	5.5	4.1	5.9

Table 4. Mean rate and intensity of use of improved maize seed and fertilizer.

	Low tropics	Dry midaltitude	Dry transitional	Moist transitional zone	High tropics	Moist midaltitude	Total
Using Improved maize varieties (%)	74.3	36.5	34	89.7	94.8	46.8	73.7
Area IMV	2.22	2.24	1.84	1.77	1.44	0.77	1.69
Proportion of maize area planted to improved maize varieties	0.88	0.84	0.85	0.96	0.99	0.79	0.93
Using chemical fertilizer (%)	6	2.5	19	70.3	87.5	24	47.2
Rate of fertilizer use (kg/ha)	63.12	49.4	130.26	126.16	143.58	72.84	127.75

adoption rate for improved maize seed compared to chemical fertilizer. This unequal rate of adoption can be explained by the simple nature of modern maize varieties relative to chemical fertilizer (Doss and Morris, 2001). Improved maize varieties are relatively inexpensive: the cost of IMV comprises a small proportion of total production costs. Primarily for this reasons, IMV should be accessible to all farmers, regardless of their resource endowment or technical skills. In contrast, fertilizer is a relatively complex technology and expensive (high cost outlay associated with cost of purchasing, transport and application).

Empirical results obtained from estimating the Heckman 2 stage models are summarized in Tables 5 and 6. Among the household head characteristics: education was positively associated with adoption of improved maize varieties ($p < 0.05$). None of the household characteristics were important in explaining the adoption of fertilizer. Access to credit and hired labour were positively and significant in explaining the adoption of improved maize varieties and fertilizer. The number of extension contacts was important in determining the adoption of improved maize varieties. Distance to market was negatively associated with adoption of fertilizer. Use of fertilizer and improved maize seed were strongly associated with adoption of improved maize seed and fertilizer. Agro ecological zones were also important in adoption of improved maize seed and fertilizer. Households in MT, LT and HT were more likely to adopt improved maize seed compared to those in dry mid-altitude zones. Similar observation was noted with respect to adoption of fertilizer. Households in MT, MM, DTZ and HT were more likely to adopt fertilizer.

Several factors were important in intensity of use of improved maize: Education and age were positively associated with adoption ($p < 0.01$ and $p < 0.05$). Hiring labour and extension contacts were also positively associated with adoption ($p < 0.05$). Use of fertilizer was strongly and positively associated with adoption of improved maize seed ($p < 0.01$). Except for households in moist mid-altitude zone, households in MT, LT, DT and HT were more likely to plant more area under improved maize seed. For intensity of use of fertilizer, except for distance to market, none of the factors were important in intensity of use of fertilizer. Distance to market was positively associated with intensity of use of fertilizer.

Conclusions

The study was conceived with the objective of identifying key factors influencing probability of adoption of improved maize varieties and fertilizer and intensity of use of fertilizer and improved maize varieties in maize growing zones of Kenya. The Heckman two stage model was adopted to analyse the adoption of improved maize varieties and fertilizer adoption decision because of the simultaneous nature of adoption of the two decisions. Credit was important in explaining the adoption of improved maize seed and fertilizer. Likewise the ability to access hired labour, a proxy for wealth was positively associated with adoption of improved maize varieties and fertilizer. Education of household head and number of extension contacts played a role in the adoption improved

Table 5. Heckman's first stage procedure results estimating factors affecting adoption of improved maize seed and fertilizer for the two zones.

	Improved maize varieties			Fertilizer		
Variable	**Coefficient.**	**Std. err.**	**P>|z|**	**Coefficient.**	**Std. err.**	**P>|z|**
Constant	-1.324	0.475	0.005	-1.321	0.496	0.008
Female headed	-0.138	0.102	0.178	-0.121	0.103	0.240
Education household head	0.022	0.010	0.028	0.002	0.010	0.833
household head	0.168	0.115	0.142	-0.138	0.118	0.242
Hired labour	0.222	0.079	0.005	0.188	0.078	0.016
Access credit	0.221	0.096	0.021	0.199	0.087	0.022
Extension contacts	0.029	0.009	0.002	0.002	0.005	0.656
Distance to market	0.022	0.035	0.523	-0.079	0.037	0.034
Fertilizer use	0.741	0.096	0.000	-	-	-
Improved maize use	-	-		0.753	0.097	0.000
Moist transitional zone	1.072	0.132	0.000	1.866	0.158	0.000
Low Tropics	0.468	0.067	0.000	-0.131	0.101	0.197
Moist mid-altitude zone	0.043	0.127	0.737	0.963	0.167	0.000
Dry transitional zone	-0.527	0.172	0.002	1.544	0.195	0.000
High Tropics	1.255	0.167	0.000	2.513	0.181	0.000
R^2	0.2906			0.4125		
Log likelihood	-710.95			-692.64		
χ	582.61			972.71		
Number observation	1712			1712		

Table 6. Heckman's second stage procedure SUR results estimating factors affecting intensity of adoption of improved maize seed and fertilizer.

Variable	**Coefficient.**	**Std error**	**z**	**P>|z|**
First equation for SUR (Intensity of adoption of improved maize seed				
Constant	0.117	0.112	1.05	0.295
Female headed	0.056	0.035	-1.59	0.111
Hired labour	0.095	0.047	2.03	0.042
Education of household head	0.009	0.003	2.61	0.009
Age of household head	0.058	0.029	2.02	0.043
Access to credit	0.081	0.042	1.91	0.056
Extension contacts	0.010	0.005	2.16	0.03
Distance to market	0.007	0.008	0.93	0.351
Fertilzer use	0.341	0.100	3.11	0.002
Moist Transitional zone	0.623	0.169	3.7	0.000
Low tropics	0.254	0.070	3.63	0.000
Moist mid-altitude	0.010	0.034	0.3	0.768
Dry transitional zone	0.194	0.08	-2.46	0.014
High Tropics	0.707	0.208	3.4	0.001
IMR[1]	0.279	0.207	-1.35	0.178
Second equation for SUR (Intensity of adoption of fertilizer)				
Constant	378.841	1385.894	0.27	0.785
Female headed	-55.676	302.454	-0.18	0.854
Education household head	-74.478	29.892	-2.49	0.013
Age of household head	-183.586	332.494	-0.55	0.581
Hired labor	182.161	263.240	0.69	0.489
Access credit	-401.728	279.561	-1.44	0.151

Table 6. Contd.

Extension contacts	-8.563	25.691	-0.33	0.739
Distance to market	250.939	102.593	2.45	0.014
Fertilizer use	-72.8287	752.025	-0.1	0.923
Moist Transitional zone	43.703	295.699	0.15	0.883
Low tropics	-335.692	291.512	-1.15	0.250
Moist mid-altitude	166.767	440.669	0.38	0.705
Dry transitional zone	251.829	577.630	0.44	0.663
High Tropics	-563.840	898.701	-0.63	0.53
IMR[2]	692.451	574.753	1.2	0.228
System R^2	0.373		R^2	0.012
Observations	1706			

[1]inverse mills ratio maize seed

[2] Inverse mills ratio fertilizer

maize varieties. Distance to market was negatively associated with adoption of fertilizer. Use of fertilizer affected the adoption of improved maize varieties and the converse was true. The findings agree with results of other studies (Doss and Morris, 2001).The area planted to improved maize varieties was positively affected by household characteristics (education and age of household head), institutional factors (number of extension contacts) and other variables such as ability to hire labour. As already mentioned this is a proxy for wealth in the study area. Use of fertilizer was strongly and positively associated with adoption of improved maize. From the findings of the results, we note the, the importance of supporting farmers with credit facilities to enhance the adoption of improved maize varieties and fertilizer. Secondly, based on the association between use of improved maize varieties and fertilizer to increase productivity, there is need to strengthen research-extension-farmers linkages to enhance the capacity of farmers to process information. The existing gap between adoption of modern maize varieties and chemical fertilizer offers an opportunity for increasing maize productivity by encouraging more farmers to use chemical fertilizers.

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