Drivers of Adoption Intensity of Certified Maize Seeds in Northern Guinea Savannah of Nigeria: A Triple Hurdle Model Approach

K. Duniya;

Institute for Agricultural Research, Ahmadu Bello University, Zaria, Agricultural Economics and Rural Sociology, Nigeria

Corresponding author email: kalatduniya@yahoo.com

Abstract:

The study sought to identify the factors influencing adoption intensity of certified maize varieties. The data used were obtained from a sample household survey of 420 maize farmers, using structured questionnaire. A triple hurdle model was adopted to estimate the determinants of adoption; considering awareness, adoption and intensity as three separate stages of the adoption decision. The result showed that the drivers of farmers' awareness, adoption and intensity of usage may not necessarily be the same, and where they are, not of the same magnitude and direction. However, age, education, membership of association and frequency of extension advice were found to be statistically significant. In addition, awareness and adoption were likely to be increased with household heads being males. It was also discovered that though some of the farmers were fully aware of the existence of some certified maize varieties, majority lacked detailed knowledge and technical know-how. There is need for creation of awareness through an excellent trained extension and restructuring of the educational sector to improve on the adoption process as well as improve maize productivity in the country. Keywords: awareness, adoption, regression, maize farmers, Nigeria

Acknowledegment: Appreciation to the Business Innovation Facility (BIF) for sponsoring the research

JEL Codes: D13, O33

#1840

Drivers of Adoption Intensity of Certified Maize Seeds in Northern Guinea Savannah of Nigeria: A Triple Hurdle Model Approach

ABSTRACT

The study sought to identify the factors influencing adoption intensity of certified maize varieties. The data used were obtained from a sample household survey of 420 maize farmers, using structured questionnaire. A triple hurdle model was adopted to estimate the determinants of adoption; considering awareness, adoption and intensity as three separate stages of the adoption decision. The result showed that the drivers of farmers' awareness, adoption and intensity of usage may not necessarily be the same, and where they are, not of the same magnitude and direction. However, age, education, membership of association and frequency of extension advice were found to be statistically significant. In addition, awareness and adoption were likely to be increased with household heads being males. It was also discovered that though some of the farmers were fully aware of the existence of some certified maize varieties, majority lacked detailed knowledge and technical know-how. There is need for creation of awareness through an excellent trained extension and restructuring of the educational sector to improve on the adoption process as well as improve maize productivity in the country.

Keywords: awareness, adoption, regression, maize farmers, Nigeria

1.0 INTRODUCTION

Seed can play a critical role in increasing agricultural productivity. It has been described as an essential, strategic, and relatively inexpensive input that often determines the upper limit of crop yields and the productivity of all other agricultural inputs. Improved crop varieties and quality seeds are the most viable ways of improving agricultural production and food security in a sustainable manner. Maize has relative yield advantage over traditional crops such as millet and sorghum. Research investment by national and international research institutions has led to the development and diffusion of improved maize varieties, and this represents a major scientific and policy achievement in African agriculture (Smale and Mason, 2014). The adoption rate of improved maize varieties was estimated to be 36.8% (Smale and Mason, 2013) as at 2006. By

2010, over 200 maize varieties had been released to farmers, out of which over 100 were subsequently grown by farmers in the 2010–11 growing season (De Groote et al., 2012).

In Nigeria, there exists a fairly developed formal maize seed production system. However, this is not as elaborate as in Eastern and Southern African countries. The system involves a network of 10 National Agricultural Research Institutes, a large number of active breeders, public production and distribution of basic seed, private sector seed companies evolving and networks of private agro-dealers. Despite these, weaknesses exist in the system that includes: Quantities of certified seeds are inadequate, production of breeder and foundation seed is low and seed distribution and information dissemination networks are poor. Improved varieties are released slowly and this enhances the dominance of the low-yielding local varieties. Requirements for certified seeds far outweighs the supply, however, effective demand is less than 10% of the requirement for all crops considered. The challenges in making this technology more commonly adopted lie in the poor understanding of seed systems, gaps in access of agricultural inputs in general and farmers' lack of knowledge about how improved varieties can affect their yields and lives. There were efforts to devise more effective seed dissemination schemes. The transformation agenda of the Federal Government and the West Africa Agricultural Productivity Programme (WAAPP) are the latest intervention in this regard.

Several studies have been conducted in relation to adoption of agricultural technologies. However, most studies (some of which include Aboulaye *et al.,* 2014; Khonje *et al.,* 2014; Mohammed *et al.,* 2014; Kudi *et al.,* 2011; Becerril and Abdulai, 2010; Akinola et al., 2010; Odoemene and Obinne, 2010; Junge *et al.,* 2009; Crost *et al.,* 2007 and Saka and Lawal, 2009 among others) analyze the household units with respect to adoption levels or rates, by employing a "one-stage" regression model (using either probit, logit or tobit) or in some cases, the double stage (hurdle) approach (using either the Heckman selection or the two separate hurdle regression by the full maximum likelihood). Only few, of which include Claytor (2015), who applied the triple hurdle model to analyse adoption with respect to livestock management practices. It is thus, important to apply this approach with respect to adoption of certified maize seed varieties so as to see the relationship that exists in the three stages of the decision process. It is against this background that a situation analysis of maize smallholder farmer incentives and

constraints for adopting certified seeds is sought to provide alternative strategies that will impact on seed and maize productivity in Nigeria.

2.0 Theoretical and Analytical Framework

Adoption and Diffusion of Innovation

The adoption and diffusion theory as elaborated by Rogers (1995) provides the theoretical foundation for this study. Adoption may be explained as a decision to make full use of information as the best course of action available. This takes place by the individual through a decision-making process that goes through a number of mental stages before making a final decision to adopt an innovation. Rogers (2003) enumerated the process as consisting of five distinct stages or steps that an individual goes through in adopting an innovation. These are: awareness, interest, evaluation, trial and adoption. To this end, adoption is regarded as the mental process through which an individual passes from first knowledge of an innovation to a decision to adopt or reject and to confirmation of this decision by continuous use.

There are four major theories that deal with the diffusion of innovations as opined by Rogers (1995). These are the innovation-decision process theory, the individual innovativeness theory, the rate of adoption theory, and the theory of perceived attributes. The innovation decision process theory is based on time and five distinct stages. The first stage is knowledge, that is, potential adopters must first of all learn about the innovation. Secondly, they must be persuaded as to the merits of the technology. Thirdly, they must decide to adopt the innovation. Fourth, once they adopt the technology, they must implement it. And fifth, they must confirm that their decision to adopt was the appropriate decision. Once these stages are achieved, then diffusion results.

The factors influencing the adoption of any technology by any group of farmers will be dependent on the target group. The factors may differ between men and women and among the different classes of farmers (including rural and urban farmers). Some farmers adopt agricultural technologies that will help improve their productivity and livelihoods. While certain factors like scale of production, long-term considerations, the history of success of past technologies, and the

endorsement of technologies by opinion leaders may be important, many other factors do influence decisions of farmers to adopt new technologies.

Akudugu, Guo and Dadzie (2012) grouped the determinants of agricultural technology adoption into three categories namely; economic, social and institutional factors. The characteristic of a technology is a precondition of adopting it. In studying determinants of adopting pest-resistant maize (IRM) variety in Western Kenya, some researchers indicated that the characteristic of the technology played a critical role in adoption decision process. They argued that farmers who perceive the technology being consistent with their needs and compatible to their environment are likely to adopt since they find it as a positive investment. Therefore farmers' perception about the performance of the technologies significantly influences their decision to adopt any initiative.

Again, farm size also plays a critical role in adoption process of a new technology. Farm size can affect and in turn be affected by the other factors influencing adoption (Lavison 2013). Farmers (mostly men) with large farm sizes are likely to adopt a new technology as they can afford to devote part of their land and income to try new technologies (Uaiene, R., Arndt, C., Masters, W. (2009). It is less economical to invest in small sized farms especially if the returns from the farms are not enough to cover the cost of investment.

Belonging to a social group also enhances social capital allowing trust, idea and information exchange (Mignouna et al., 2011). Farmers within a social group learn from each other the benefits and usage of a new technology.

Analytical Framework

There are several methods for estimating adoption models in the literature. Most studies (some of which of recent, include Khonje *et al.*, 2014; Mohammed *et al.*, 2014; Kudi *et al.*, 2011; among others) adopt either the probit, logit or tobit models in analyzing the determinants of adoption. Most of these analyze the household unit with respect to adoption levels or rates, by employing a "one-stage" regression model. One major limitation to all of these methods is that each is reliant on the implicit assumption that all observations (and therefore all members of the population

analyzed) are adopters of the technologies. In some cases, such two-tiered analysis may indeed be appropriate.

The "two-stage" model, otherwise known as a "double hurdle" model, later became of increasing use by researchers. Akinola *et al.* (2010) applied the double stage model to study the determinants of adoption and intensity of use of balanced nutrient management systems technology in the northern guinea savannah of Nigeria. The first stage involved an application of probit model, while in the second stage, the log- normal regression model was used to determine the intensity of adoption.

Abdoulaye *et al.* (2014) also applied the bivariate probit (a two stage regression) model in their study on the awareness and adoption of improved cassava varieties and processing technologies in Nigeria. The first stage was a binary probit used to separate the respondent s into two groups (those who are aware of the technologies and those who are not aware), while the second stage utilized a probit model again to analyse the decision to use (adopt) the improved cassava varieties. A similar study by Obuobisa-Darko (2015) and Awotide *et al.* (2014) applied the double hurdle model in assessing the extent and determinants of adoption of improved technologies in which the first stage involved the decision to adopt while the second stage involved the decision on the proportion of area to be devoted to the improved technologies. However, in studies such as Abdoulaye *et al.* (2014) where awareness and adoption are considered as separate stages, it does not allow the researcher to identify determinants of the technology usage or intensity itself, which is the necessary precursor to any adoption related decisions.

There are two methods available for estimating double hurdle models: Heckit and standard Full Maximum Likelihood. Both methods could arguably be employed in this study, since the first two stages can be thought of as a selection (Heckit) double hurdle, while the second and third stages represent a combination of corner solution double hurdles. In this analysis of adoption, a 3-stage, or triple hurdle model was thus employed. Starting with a representative sample, the first stage distinguishes maize farmers who are aware of the existence of any certified maize seed variety and those who are not, using logit analysis. In the second stage, similar to the first stage, a logit was also used to identify factors within producing households which determine whether

they are adopters or non-adopters of at least one of the certified maize seed varieties. Finally, in the third stage, the determinants of adopters' proportion of land size devoted to certified maize seed varieties were identified in separate generalized linear regression, which are all appropriate given the truncated nature of the dependent variables. The 3-stage model also allows for the simultaneous existence of both types of zeros. In the case of adoption, that is, the model allows for the variables to be zero either because the household selected themselves not to adopt altogether or not.

The binary logistic model is employed in this study because it has advantage over the other models in the analysis of dichotomous outcome variable in that it is extremely flexible and easily used model from mathematical point of view and results in a meaningful interpretation. The parameter estimates of the model are asymptotically consistent and efficient. The standardised coefficients correspond to the beta-coefficients in the ordinary least squares regression models and above all, it is relatively easy to compute and interpret. The cumulative logistic probability model is econometrically specified as follows:

$$Pi = F(Z_i) = F(\gamma + \sum \lambda_i X_i) = \left[\frac{1}{1+e^{-zi}}\right] \quad \text{..... (1)}$$

Where P_i is the probability that a farmers will adopt at least one improved rice variety or not given X_i; e denotes the base of natural logarithms, which is approximately equal to 2.718; X_i represents the *ith* explanatory variables; and γ and λ are parameters to be estimated. The logit model could be written in terms of the odds and log of odds, which enables one to understand the interpretation of the coefficients. The odds ratio implies the ratio of the probability (P_i) that a farmer is aware or is an adopter to the probability ($1\text{-}P_i$) that the farmer is not aware or a non-adopter, given by:

$$(1\text{-}P_i) = \left[\frac{1}{1+e^{zi}}\right] \quad \text{..... (2)}$$

Therefore,

$$\left[\frac{P_i}{1-P_i}\right] = \left[\frac{1+e^{zi}}{1+e^{-zi}}\right] = e^{zi} \quad \text{..... (3)}$$

The logit model is based on the cumulative logistic distribution. Hence, the natural log function is expressed as:

$$L_i = In\left[\frac{P_i}{1-P_i}\right] = Z_i \quad \text{……..……..…….. (4)}$$

Where;

L_i = is log of the odd ratio, which is not only linear in X_i but also linear in the parameters and

P_i is the probability of adopting and ranges from 0 to 1, such that Y_i is the function of the explanatory variables (X) with coefficients (β) which is simply expressed as:

$$Y = X_i'\beta + \mu_i \quad \text{..... (5)}$$

3.0 MATERIALS AND METHODS

Study Area: The survey was conducted in Nigeria. Nigeria is the most populous African country with a population of about 174,507,539, as obtained from the 2013 national census report, a total land area of about 923,768km^2 and a population density of about 188.9/km^2. The Northern part of the Country is made up of 19 States out of the 37 states in the country. It houses three (3) out of the six (6) Geo-political zones of the country and lies between latitude 4-14^{0}N and longitude 7.4-11^{0}E. Vegetation of the area is savannah: the Sahel, Sudan and Guinea savannah zones. The region is marked by two distinct seasons: dry and rainy seasons, with the intensity of rainfall increasing as one move southwards. Major occupation is farming which include crop cultivation and animal rearing.

Data collection: Primary data were used and information were collected based on the following thematic areas: (i) Socio-economic and demographic characteristics of household members (ii) awareness, adoption and perceptions on the use of certified maize seeds, (iii) area of land for the production of certified maize seeds, (v) knowledge and use of recommended agronomic practices, (vi) information sources on seed availability. The instrument used for the survey was the questionnaire, developed by the resource team, and administered using well trained enumerators. A cross section of an interview with a female maize farmer is shown thus:

Sampling: The selection of households was achieved through purposive random sampling ensuring that households interviewed also represented the categories of people (male and female) with information on use of certified maize seeds. Four major maize growing states in the Guinea savanna agro-ecological zone were selected for the survey. These are Katsina, Kaduna, Nasarawa and Niger States. Two Local Government Areas (LGA's) were then selected purposively from each of the states except Benue (from which four Local Government Areas were selected) for various reasons; being the prominent maize producing areas, having regional grain market, important maize producing areas with high frequency of women involved in production and processing. Four (4) villages with the highest level and intensity of maize production activities were selected from each LGA. Finally, a targeted average of ten respondents was made from each village based on high participation in maize farming activities as well as the ease of accessibility of farmers, giving rise to a total of 420 households.

Data Analysis: Descriptive (summary statistics) and inferential (3-tiered/ triple hurdle model) statistical methods were employed to analyse the data collected.

Model Specification

A "triple-hurdle" model was employed to determine the factors influencing adoption intensity of certified maize seeds. It accounts for the awareness, adoption and intensity of usage as separate step processes in the adoption decision, such that, two separate hurdles must be crossed before a level of farmers' adoption intensity (the third) can be observed. The first hurdle involves whether the farmer is aware of certified maize seeds. A binary logit regression model was used such that Y = 0 if a farmer is not aware of any existing certified maize seed varieties and 1, if a farmer is aware. This is expressed as:

$$Y_{i1}^{**} = Z_i\alpha + \nu_i \quad \text{..... (6)}$$

The second hurdle which is conditional on the first hurdle involves whether the farmer decided to adopt or not. The binary logit was also applied such that Y = 0 if a farmer did not adopt and 1 if a farmer adopts as shown in the expression:

$$Y_{i2}^{**} = X_i\beta + \mu_i \quad \text{..... (7)}$$

Third Hurdle, which is also conditional of the second hurdle, involves the portion of farm size devoted to the cultivation of certified maize seed variety (intensity of adoption). A generalized linear regression was adopted such that the dependent variable, Y, was measured as a proportion of farm size devoted to the cultivation of certified maize seed varieties. The explicit expression of the model is given as follows:

$$Y_{i3}^{**} = Q_i\delta + \upsilon_i \quad \text{..... (8)}$$

where Y_{i1}^{*} is a latent variable describing the farmer's awareness, Y_{i2}^{*} is a latent variable describing the farmer's decision to adopt and Y_{i3}^{*} is the latent variable describing the farmer's intensity of adoption, measured as a proportion of total land size devoted to cultivation of certified maize seed varieties. The dependent variables are determined by independent variables

such as socio-economic characteristics of farmers, institutional characteristics and the seed technologies' characteristics.

The first hurdle, which involves the determinants of awareness can be expressed explicitly as:

$$Y_{i1}^{**} = \alpha_0 + \alpha_{i1}Z_{i1} + \alpha_{i2}Z_{i2} + \alpha_{i3}Z_{i3} + \alpha_{i4}Z_{i4} + \alpha_{i5}Z_{i5} + ... + \alpha_{i9}Z_{i9} + \nu_i \text{ .....(9)}$$

Where, $\alpha_{0,}$ is an intercept, or constant term; $\alpha_1 \ldots \alpha_{n,}$ are coefficients of independent variables; $Z_1 \ldots Z_n$, are independent variables and ν_i, is a disturbance or error term.

The second hurdle can explicitly be expressed as:

$$Y_{i2}^{**} = \beta_0 + \beta_{i1}X_{i1} + \beta_{i2}X_{i2} + \beta_{i3}X_{i3} + \beta_{i4}X_{i4} + ... + \beta_{i12}X_{i12} + \mu_i \text{ .....(10)}$$

Where: β_0 is an intercept, or constant term; $\beta_1 \ldots \beta_n$ are coefficients of independent variables; $X_1 - X_n$ are independent variables and $\mu_{i,}$ is a disturbance or error term.

For the third hurdle, which involves the factors influencing the intensity of adoption, the explicit expression of the model is as follows:

$$Y_{i3}^{**} = \delta_0 + \delta_{i1}Q_{i1} + \delta_{i2}Q_{i2} + \delta_{i3}Q_{i3} + ... + \delta_{i13}Q_{i13} + \upsilon_i \text{ .....(11)}$$

$$Y_{i3}^{**} = \frac{\text{Area planted with certified maize seed varieties (ha)}}{\text{Total area devoted to maize production (ha)}} \text{ ..... (12)}$$

Where, δ_0 is an intercept, or constant term, $\delta_1 \ldots \delta_n$ are coefficients of independent variables, $Q_1 \ldots\ldots Q_n$ are independent variables and υ_i is a disturbance or error term.

The assumption of these stages to be independent is supported by several studies including Asfaw *et al.* (2011), Obuobisa-Darko (2015); Johnson *et al.* (2014)

Hypothesized Effects of Explanatory Variables

The explanatory variables used in the model are found in Table 1. Respondents were faced with three decisions: The first was whether the respondent was aware of any certified maize seed

variety or not, then the factors influencing awareness were determined as socio-economic and communication/ information sources. Respondents who were aware were then asked if they had adopted. Here, non-monetary variables included in the first hurdle were also included in the second hurdle in addition to seed cost (which is a monetary variable) and accessibility. It is logical that variables directly affecting a respondent's financial circumstance be included in the second and third hurdles. The introduction of the seed cost variable reflects a change in the context of the decision from a general set of factors of awareness to the probability of adopting. While the variables' effects on these decisions are expected to be similar, the significance levels are expected to differ. For example, if age is hypothesized to be negative in the awareness level, there would be no reason to believe that it would change sign in the adoption decision. The third stage asked for the size of land used in cultivating certified maize seeds. The variables included in the awareness and adoption stages are mainly farmer and farm characteristics. The decision of farm size proportion (devoted to cultivating certified maize seed variety) is also assumed to be directly influenced by some of the same variables, as such; these variables are also included in the proportion of farm size regression.

4.0 RESULTS AND DISCUSSION

Description and Summary Statistics of Variables used in the Model

A summary statistics of the variables included in the model is presented in Table 1. The standard deviations show how far the observations are from the mean of the sample surveyed.

Table 1: Descriptive statistics of variables used in the model

Variables	Description	Mean	Standard Dev.
Dependent			
Awareness	1 if respondent is aware of any certified maize variety, 0 otherwise	0.612	0.091
Adoption	1 if respondent adopts at least one certified maize variety, 0 otherwise	0.794	0.493
Farmprop	Proportion of land size devoted to cultivation of certified maize seed varieties	1.457	2.517
Independent			
Age	Number of years of the respondent	45.626	11.899

Gender	Sex of respondent measured as 1, if male and 0, if female	0.407	0.491
Income	Total amount of money obtained by a farmer in naira per annum	439131	214938
Education	Level of formal education attained by the respondent, measured in number of years spent schooling	3.327	2.031
Total farm size	Total farm size owned by a respondent measured in hectares	7.755	6.496
Access to credit	Total amount of credit the respondent had received from any credit sources or institution in naira	102011	113816
Seed cost	Amount in naira paid by a farmers to purchase 1kg of certified seed	74.010	102.427
Male household	Number of males in the household	6.805	4.559
Female household	Number of female in the household	7.244	7.797
Extension visits	Total number of visits by extension within the last 12 months	2.043	2.769
Association	Farmers' membership of any association measured as 1, if a member of any, otherwise, 0.	0.571	0.495
Accessibility	Farmer's accessibility to seeds, measured as 1, if a farmer has access and 0, otherwise.	0.613	0.341

Determinants of Awareness, Adoption and Intensity

The first two decisions; awareness and adoption, are modeled using logit regressions, while the third, adoption intensity is a continuous variable with a binary range. Of more interest are the results from the triple hurdle model, of which it is significant overall as revealed by the F- value. Five of the nine variables are significant in the 1st hurdle, eight out of twelve in the 2nd hurdle and eight out of twelve in the 3rd hurdle. Age is significant and negatively associated with awareness. Although it switches sign in the second hurdle (relative to the first hurdle), it became

insignificant in the 3rd hurdle, which possibly indicates that among those producers who are aware of the certified maize seed varieties, older producers are more influenced by information than younger producers.

Table 2: Regression estimates of the adoption decision of farmers in the three stages

Variables	**1st hurdle (awareness)**	**2nd hurdle (adoption)**	**3rd hurdle (farmprop)**
Age	-0.055 (0.015)**	0.061 (0.016)***	-0.010(0.016)
Gender	0.006 (0.062)	0.016 (0.037)	0.849 (0.243)***
Income	1.485 (0.662)**	2.006 (0.366)***	1.551(0.664)**
Education	0.195 (0.077)**	0.287 (0.083)**	0.254(0.087)**
Occupation	0.062 (0.180)	0.075 (0.180)	0.044(0.182)
Total farm size	_____	2.783 (0.601)***	0.248(0.101)**
Seed cost	_____	-0.231 (0.038)**	0.001(0.001)
Association	1.439 (0.339)***	1.744 (0.373)***	1.802(0.379)***
Extension visits	0.120 (0.056)**	0.170 (0.058)***	0.138(0.060)**
Household size	_____	_____	-0.240(0.040)***
Seed accessibility	0.014(0.018)	0.012(0.004)	0.009(0.007)
Access to credit	0.014(0.039)	0.256(0.256)	0.840(0.350)
R2	0.458	0.667	0.650
F	26.11***	18.06***	5.04***

, **, *, imply significant at 10%, 5% and 1% level respectively*

Results show that factors such as gender of the head of household, the age of a farmer and access to credit contribute significantly to the probability of adopting certified maize seed varieties. The cost of seeds is negative and significant in the 2nd hurdle, but insignificant in the 3rd. The higher the seed cost, the less likely a respondent will access and adopt. Total farm size is also positive and significant. The results indicate that farmers with more land are more likely to adopt new technologies. Unlike in the awareness stage, the percent of income from farm production and total income were not found to be significantly different from zero. The coefficient for gender of

household head is positive and significant at suggesting that the probability of adopting at least one certified maize variety diminishes with being a female farmer.

Marginal effects

Calculating the marginal effects for this triple hurdle model is not straightforward, and it is important to note that independent variables included in superior tiers indirectly influence the marginal effects of dependent variables in lower tiers even if those variables are not in the equation (Jensen et al., 2015). The marginal effects are estimated using a finite difference approximation algorithm suggested by Cameron and Trivedi (2009) and applied by Jensen et al. (2015), where the variable's marginal effect is equal to the mean difference between the unconditional and conditional means. For the binary decisions (awareness and adoption), the marginal effects are derived from the numerator and denominator of the bivariate cumulative density ratio in the conditional mean expression. The results are thus shown in Table 3.

Table 3: Marginal Effects for Triple Hurdle Regression

Variables	**Marginal effects**		
	Awareness	**Adoption**	**Farmprop**
Age	0.041	0.008	0.010
Gender	0.032	0.113	-0.849
Income	0.421	0.276	-1.551
Education	0.117	0.178	0.254
Occupation	0.221	0.115	0.044
Total farm size	------	0.782	-0.248
Seed cost	------	0.041	0.001
Association	0.845	0.513	1.802
Extension visits	0.149	0.199	0.138
Household size	------	0.018	-0.240
Seed accessibility	0.102	0.114	0.009
Access to credit	0.124	0.311	0.841

The marginal effects of the third hurdle are same as the coefficients since the dependent variable is continuous within the binary range and hence, analysed using a generalized linear regression model. Being a female headed household reduces the propensity to adopt certified maize seed varieties. The age of the farmer returned a positive and significant marginal effect suggesting that a percentage increase in age increases the propensity to adopt improved maize seed varieties.

The findings might be explained by the fact that although older farmers face higher search costs for information on new technologies which reduces their exposure, once they overcome the information barrier, older farmers are quick to adopt them because they have a higher resource endowment than young farmers. Another explanation could be that young people have more viable options or alternative investments hence may delay adoption of improved maize seed varieties.

The membership of association had a negative and significant marginal effect indicating that although more likely to know about the existence of improved varieties, membership lowers the propensity to adopt certified maize seeds. A possible explanation for this can be drawn from innovation-diffusion and economic constraint paradigms of the adoption model. The innovation-diffusion paradigm is based on the assumption that the technology is technically and culturally appropriate but the problem of adoption is one of asymmetric information and very high search costs. The economic constraint paradigm states that input fixity in the short run, such as access to credit, land, labour or other critical inputs limits production flexibility and conditions technology adoption decisions (Uaiene et al., 2009). This finding could suggest that farmers with membership of organizations overcome information search costs and have access information on certified maize seed varieties, as consistent with findings by Simtowe et al. (2016).

Again, consistent with the economic constraint paradigm of adoption models, access to credit returned an expected positive and significant marginal effect. Indeed the household that borrowed some money from the lending institution increased the propensity of adopting certified maize seeds. Seeds are not a lumpy investment, but credit and cash constraints can be important because adoption of certified maize seeds might entail purchasing seed, hiring extra labour which increases the cost of production. With the availability of credit a household can purchase improved seed and hire extra labour. In this study few of the farmers (as seen earlier in table 1) indicated that they borrowed money from either credit institutions or informal institutions, despite the high demand for credit. This finding suggests that there exists a great scope for increasing the cultivation of certified maize seeds through an improved access of farmers to credit markets. Seed cost is negative and significant in the 2nd hurdle. Implying that as seed cost

increases, the likelihood of adoption and intensity decreases. Also, for every one percent increase in income, the likelihood of adoption and intensity increases. While older respondents were less likely to be aware, they were more likely to adopt the certified maize seeds varieties if aware.

5.0 CONCLUSION AND RECOMMENDATIONS

This paper has provided estimates of adoption intensity and the determinants of adoption for the certified maize varieties in Nigeria and has shown the importance of appropriately controlling for exposure and selection bias when assessing the adoption intensity of a technology and its determinants. The unawareness bias of about 40% suggests that there is potential for increasing the adoption rate of certified maize seeds, if its diffusion to the population can be completed and if other economic constraints are addressed. The observation that only about 60% of the farmers was aware of at least one of the certified maize varieties underscores the urgent need for scaling up efforts to disseminate information about the varieties and their potential benefits among farmers. Methods include on-farm trials, demonstration plots controlled by agricultural extension agents, field days for farmers, and agricultural shows to which farmers are invited need to be intensified.

ACKNOWLEDGEMENTS

Appreciation to the Business Innovation Facility (BIF) for sponsoring the research.

REFERENCES

Abdoulaye T., Abass A., Maziya-Dixon B., Tarawali G., Okechukwu R., Rusike J., Alene A., Manyong V. and Ayedun B. (2014). Awareness and adoption of improved cassava varieties and processing technologies in Nigeria. *Journal of Development and Agricultural Economics, 6 (2);67-75*

Asfaw, S., Shiferaw, B., Simtowe, F., and Haile, M.G. (2011). Agricultural technology adoption, seed access constraints and commercialization in Ethiopia. *Journal of development and agricultural economics 3(9); 436–447*

Awotide, B. A., Diagne, A., & Omonona, B. T. (2014). Impact of Improved Agricultural Technology Adoption on Sustainable Rice Productivity and Rural Farmers' Welfare in Nigeria: A Local Average Treatment Effect (LATE) Technique. A paper Prepared for Presentation at the African Economic Conference, October 30- November 2, 2012 at Kigali, Rwanda

Becerril, J., & Abdulai, A. (2010). The impact of improved maize varieties on poverty in Mexico: A propensity score-matching approach. World Development, 38(7), 1024–1035.

Claytor, H.S. (2015). Cattle Producers East of the 100th Meridian: A study of afforestation, adoption and use of pasture management practices. "University of Tennessee. http://trace.tennessee.edu.utk_gradthes/3353

Crost, B., Shankar, B., Bennett, R., & Morse, S. (2007). Bias from farmer self-selection in genetically modified crop productivity estimates: Evidence from Indian data. Journal of Agricultural Economics, 58(1), 24–36.

De Groote, H., Gitonga, Z., Smale, M., Kasuta, E., Asare-Marfo, D., Sonder, K., & Birol, E. (2012). Adoption and diversification of modern maize varieties in Zambia: A baseline report prepared for Harvest Plus Washington, DC: Harvest Plus, Mimeo

Khonje, M., Manda, J., Alene, A. D. and Kassie, M. (2015) Analysis of Adoption and Impacts of Improved Maize Varieties in Eastern Zambia. *World development 66; 695 – 706*

Mohammed, U., Olaleye, R.S., Tologbonse, E.B., Ndanitsa, M.A., & Umar, I.S. (2014). Determinants of women involvement and adoption of improved methods of groundnut processing technologies in three (3) local government areas of Niger State, Nigeria. *Journal of agriculture and veterinary science, 7(12), 29-34*

Rogers, E. M. (1995). Diffusion of Innovation: 4th edition. Free Press. New York, USA

Rogers, E. M. (2003). Diffusion of Innovation: 5th edition. Free Press. New York, USA

Smale, M. and Mason, N. (2013). Hybrid seed, income, and inequality among smallholder maize farmers in Zambia. Indaba Agricultural Policy Research Institute (IAPRI) Working Paper 72. Working Paper. Lusaka, Zambia. Retrieved from <http://www.aec.msu.edu/fs2/zambia/index.htm>

Smale, M., and Mason, N. (2014). Hybrid seed and the economic well-being of smallholder maize farmers in Zambia. *The Journal of Development Studies.* http://dx.doi.org/10.1080/00220388.2014.887690.