Variety Awareness, Nutrition Knowledge and Adoption of Nutritionally Enhanced Crop Varieties: Evidence from Kenya

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Acknowledegment: THe authors of this paper akcnowledge the Germany Federal Ministry of Food and Agriculture for sponsoring this study through the Agriculture and Diet Diversity in Africa (ADDA) Project.

JEL Codes: Q12, Q12

#1080

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This paper uses the Average Treatment Effect framework to determine population potential adoption rates of KK 15 beans when awareness of the variety and knowledge of nutrition attributes is not a constraint. The KK 15 bean is a new variety that contains high levels of zinc and iron, and thus important in the fight against micro-nutrient deficiency in Kenya. The results show that actual population adoption rates of KK 15 beans was 21 percent for the variety aware group, and 31 percent for nutrition attribute knowledge aware group. After controlling for heterogeneous information exposure, the results show that the potential population adoption rates of KK 15 beans would have been 28 percent for variety awareness unconstrained, and 38 percent for nutrition knowledge unconstrained. Coefficients of the ATE model to determine factors influencing adoption are bigger than classical models, implying that the classical model under-estimates the effects. The adoption gap resulting from KK15 variety awareness exposure is 9 percent, and 6 percent for nutrition attribute knowledge. Policies aimed at improving adoption of bio fortified crops need to focus on improving access to information on the varieties and their nutrition attributes through 'nutrition sensitive' extension services.

Keywords: Nutrition attributes, average treatment effect, variety awareness

1. Introduction

It is estimated that close to a billion people globally are undernourished (Food and Agriculture Organization of the United Nations [FAO] et al., 2015). In Kenya, well over 10 million people, who make 24.3 percent of the population, are undernourished (FAO, 2014). The poor state of nutrition is a result of conflict, climate change leading to frequent droughts and water shortage, price volatility, among other causes (FAO et al., 2015; Nelson et al., 2009). Consequently, undernutrition is a major concern for not just governments but also international development organizations due to the huge cost burden on economies and loss of lives (Horton and Ross, 2003; Stein and Qaim, 2007).

Recent work of research and program interventions in agriculture has revealed the significance of the sector in combating undernutrition in developing countries (Honfo et al., 2010; Masset et al., 2012; Fanzo et al., 2013; Jones et al., 2014). This new approach is based on the premise that majority of the population in developing countries are subsistence farmers living in rural areas. Bio fortification, for instance, has been touted as an innovative method of alleviating micronutrient malnutrition in developing countries (Pfeiffer and McClafferty, 2007). The technique employs modern technology in plant breeding to raise the micronutrient density of staple crops.

Empirical evidence from Vitamin A biofortification of Orange Fleshed Sweet Potatoes (OFSP) shows that targeted agricultural programmes for nutritionally enhanced food crops have a positive nutritional effect (Jaarsveld et al., 2005). For such programmes to be effective however, farmers have to grow these crops and consume them. There exists rich literature on adoption of agricultural technology. However, these studies focus on technology that is superior in productivity, pest and disease resistance, among other productivity related characteristics. Adoption of recently released nutritionally rich varieties is however not expected to follow similar trends as the typical agricultural technology. These crops are not necessarily superior in productivity or marketability than the parent crops. They are thus adopted mainly for their nutritional benefits.

Very few studies have focused on adoption of nutritionally enhanced varieties or bio fortified crops (Krivanek et al., 2007; Kaguongo et al., 2010; Okello et al., 2014; Shikuku et al., 2014). These studies have limitations in that they assume homogenous information exposure in the population and fail to control for uneven diffusion of information and consequently awareness and knowledge of nutrition characteristics of the crops by farmers. Both awareness of the new varieties and knowledge of the nutritional benefits is an important prerequisite for adoption to happen. Diagne and Demont (2007) show that the observed adoption rates as calculated from sample computation and classical adoption models are not accurate when exposure to the technology is not complete in the population.

Diagne and Demont (2007) note that the classical adoption models do not accurately estimate population adoption rate due to non-exposure bias and selection bias. Non exposure bias results in underestimation of population adoption rate as farmers not exposed to a new technology cannot adopt it. Similarly, selection bias results from adoption by farmers who get exposed first, or ‘progressive’ farmers who most likely interact with technology promoters such as extension officers, leading to overestimation of population adoption rate.

In order to eliminate bias, Diagne and Demont (2007) propose using the Average Treatment Effect (ATE) framework. The ATE framework, as used in impact assessment studies can be applied in adoption to denote the population potential mean adoption outcome, conditional on a vector of covariates. The population adoption rate relates to the Average Treatment Effect (ATE), whereby the outcome of interest in this case can be a binary adoption status (yes/no) or adoption rate/intensity, while treatment is exposure to the intervention. Woodridge (2002) defines ATE as the expected effect of an intervention/treatment on a person randomly selected from a population.

This study argues that exposure to the variety analyzed by Diagne and Demont (2007) is not sufficient for adoption of new varieties bred for nutrition. In addition to exposure to variety, knowledge of the nutritional attributes of the variety is a prerequisite to adoption of these varieties. A farmer may be aware of the variety but not aware of the unique nutritional benefits of the variety. If this knowledge is not taken in to consideration, then the adoption rate may be under estimated. Similar argument is presented by Kabunga et al. (2012) on farmer's knowledge of productivity traits of tissue culture bananas in Kenya and Nguezet et al. (2013) on awareness and access to seed for NERICA rice farmers in Nigeria. The two studies however focus on commercial crops and are not related to nutrition.

The study adopts the ATE framework proposed by Diagne and Demont (2007) to show actual and potential adoption rates of KK15 beans variety in Western Kenya. The KK 15 bean variety is a new bean variety bred by Kenya Agricultural & Livestock Research Organization. It contains high levels of zinc and iron, and thus important in the fight against micro-nutrient deficiency in Kenya (Kenya Agricultural & Livestock Research Organization [KALRO], 2016). The variety is also bred to resist root rot disease, which devastates many other bean varieties, and is early maturing, taking two and half months.

A local Non-Governmental Organization (NGO), Africa Harvest, had been promoting the variety in the study area for a year before data was collected. The promotion targeted selected common interest groups in the area, as such it was expected that exposure was not complete in the population. This study estimates the variety awareness unconstrained potential adoption rates, and nutrition attributes knowledge unconstrained potential adoption rates for KK15 beans in Kenya. Determinants of awareness and adoption, as well as farmer perception of the variety are also estimated.

1. STUDY METHODS

1.1. Analytical Framework

Recent literature on adoption of agricultural technology has shifted from use of classical adoption models such as probit and logit due to inconsistency of results ensuing from non-exposure bias and selection bias (Diagne and Demont, 2007; Kabunga et al., 2012; Nguezet et al., 2013). Classical models analyse adoption using samples selected either randomly or otherwise from the population, regardless of whether or not the respondents are aware of the technology. However, diffusion of information on a new technology in the population is rarely complete, hence some of the sampled respondents are usually not aware of the technology.

This creates non-exposure bias, because farmers who are not aware of the technology cannot be said to have adopted, even if they do so unknowingly (Diagne and Demont, 2007). As a result, the observed population adoption rate underestimates the true population adoption rates if incomplete exposure to the technology is not controlled for. In addition, even if only the exposed farmers were to be considered for analysis, the study would suffer from selection bias because farmers self-select in to exposure. Extension officers have been known to target the so called 'progressive' farmers for promotion of new technologies. Such farmers are likely to get exposed first, and are also more likely to adopt.

According to Diagne and Demont (2007), the true population adoption rate corresponds to the Average Treatment Effect (ATE) applied in impact assessment literature. The ATE is defined as the expected effect of an intervention/treatment on a person randomly selected from a population (Woodridge, 2002). In order to determine the treatment effect, then one must define the counterfactual. Assuming that y_1 is outcome of treatment on an individual and y_0 is outcome without treatment, the individual cannot be observed in both states, which is essentially a 'missing data' problem.

The first outcome of interest is the ATE, which in adoption terms is the population potential mean adoption outcome, conditional on covariates, x. The second outcome of interest in the current study will be the Average Treatment Effect on the Treated (ATE'T), defined as the expected effect on those who were actually exposed to the intervention (Woodridge, 2002). The current study will adopt the ATE framework as proposed Diagne and Demont (2007) and expanded by Kabunga et al. (2012) and Nguezet et al. (2013). Two levels of exposure will be considered; awareness of the intervention (KK15 bean variety), and knowledge of the nutritional attributes of the variety.

In the first stage, respondents were asked whether they knew about KK15 bean variety; the answer was binary and is denoted in by *r* in this study (*r=1* if 'yes' and *r=0* if 'no'). Only the farmers who answered in affirmative the first question were asked the second/follow-up question. The follow-up question sought to know whether the respondent knew the unique nutritional attributes of the variety, in this case rich in iron and zinc. The answer to the follow-up question was also binary, denoted in this study by *k* (*k=1* if 'yes' and *k=0* if 'no'). A few follow up questions on the nutrition attributes of KK15 beans were asked to authenticate the answer if it was a 'yes'. Farmers were also asked the quantity in kilograms they had planted.

Following Woodridge (2002), the population potential mean adoption outcome (ATE), conditional on covariates, x, is presented in equation one.

$$ATE = E(y_1 - y_0 | x) \quad \ldots 1$$

whereby;

y_1 is the potential adoption outcome of a farmer when exposed to the intervention

y_0 is the potential adoption outcome of a farmer when not exposed to the intervention

The Average Treatment Effect when the farmer is aware of the variety (variety awareness unconstrained) is expressed in equation as:

$$ATE'T_r = E(y_1 - y_0 | x, r = 1) \quad \ldots 2$$

The Average Treatment Effect when the farmer is both aware of the variety and knowledgeable on the nutrition attributes of the variety (variety awareness and nutrition knowledge unconstrained) is expressed as:

$$ATE'T_{rk} = E(y_1 - y_0 | x, r = 1, k = 1) \quad \ldots 3$$

The third outcome of interest is what Nguezet et al. (2013) define as Average Treatment Effect on the Untreated (ATE'U), which is expressed as:

$$ATE'U_{rk} = E(y_1 - y_0 | x, r = 0, k = 0) \quad \ldots 4$$

The three outcomes of interest are consistent and unbiased when estimated using the ATE framework, subject to a condition that the distribution of r and k (treatments) are independent of y_{10} and y_{11} (potential outcome), and conditional on a vector of covariates x (Woodridge, 2003; Nguezet et al., 2013). The estimations were carried out on the STATA 13 statistical softaware, with the user written add-on '*adoption*' by Diagne and Demont (2007).

The *'adoption'* command can be applied in two stages. In the first stage, the factors affecting exposure are explained, while in the second stage explains the factors that affect adoption. The variables in the first stage and second stage need not be the same, which is practical, because some variables that influence awareness do not necessarily influence adoption. This study extends the work of Diagne and Demont (2007) by including a second level of information exposure; knowledge of the nutrition attributes of the KK15 bean variety. Two models are estimated in two forms for each model; the linear regression and probit regression, both ATE and classical forms in order to compare the results.

In policy and programme terms, awareness of the variety and knowledge of the unique nutritional benefits of the variety are different concepts. Majority of information that farmers usually will have relates to just knowing the variety. However, without knowing the nutritional benefits of the variety, a farmer cannot be said to have adopted the variety for nutrition purposes. Farmers who are aware of the variety and not nutritional benefits may not adopt if they consider the variety equivalent to the others in terms of productivity or commercialization. Including knowledge of nutrition benefits in the model therefore avoids underestimating adoption rates due to failure to account for non-adoption explained by lack of knowledge of nutrition benefits. This is important for policy as the variety is not bred for superior productivity like most agriculture technologies, but for nutrition in terms of extra micronutrients. According to Diagne and Demont (2007), access to seed is an important policy issue in adoption, it is not the focus of this study since Africa Harvest availed seeds to interested buyers.

1.2. Data Sources

Data was collected from farmer groups in Western Kenya Counties of Kisii and Nyamira in 2016. The data was collected after one year of active promotion of KK15 beans by a local NGO, Africa Harvest. The promotion took place through training delivered to groups that were randomly selected from a list of all common interest and farmer groups that existed at the time across the two counties. It is important to note that these groups existed before the selection for trainings begun and that groups were randomly sampled for training which eliminated possible bias. Because promotion of the KK15 bean variety was not carried out among all groups, it was expected that penetration of information was incomplete in the population.

Data was collected from 661 respondents who were members of 48 groups randomly selected from a list of all common interest groups and farmer groups across the two counties. Between 15 and 20 respondents were selected randomly from the groups selected in the first stage. The respondents were drawn from 36 groups that had received training and 12 that had not. It is worth noting that not all farmers that were members of groups selected for training attended the training sessions. The respondents were interviewed using questionnaires designed and tested in the field and administered in local language by trained enumerators.

2. RESULTS

Descriptive Statistics

Table 1 presents descriptive results of farmer and household socioeconomic characteristics disaggregated to adoption status. A t-test was carried out to determine differences in the characteristics between the two categories.

Table 1: Descriptive Results for household socio-economic by adoption status

Variables	Means			t-test
	Adopters (N=137)	Non-adopters (N=534)	Total Sample (N=661)	
Proportion of male farmers (%)	73.7	74.7	74.5	0.24
Age of HH head (years)	53	49.8	50.5	-2.68***
Education of HH head (years)	9.1	8.9	8.9	-0.58
Age of female spouse (years)	48	44.6	45.3	-2.81***
Education of female spouse (years)	7.7	8.3	8.1	1.76*
Size of land owned (acres)	1.6	1.4	1.5	-1.17
Number of extension visits	6.2	2.6	3.3	-9.86***
Household size	5.5	5.4	5.5	-0.38
Distance to village market (Kms)	2	1.9	1.9	-0.53
Distance to agricultural produce market (Kms)	3.9	4.5	4.4	1.46
Distance to tarmac road (Kms)	3	3.4	3.3	0.81
Farm diversity (crop count)	12.4	11.1	11.3	-4.06***
On farm income (1000 Kshs)	68.7	10.6	76.5	-2.72***
Off farm income (1000 Kshs)	132.9	116.6	120	-1.11

Notes: *, **, and * show that mean values for KK15 adopters are significantly different from those of non-adopters at the 1%, 5%, and 10% respectively. Exchange rate US $1 = K.shs 103.**

The results reveal that there are no significant differences between adopters and non-adopters in regards to gender of household head. Although majority of farmers that were interviewed were male (75 percent), the t-test does not reveal gender differences between the two categories. Previous studies have revealed a significant role of gender in adoption of nutrition related agricultural technologies (Shikuku et al., 2014).

The mean age of adopters is significantly different than that of non-adopters. Nutrition requirements change as individuals advance in age, thus adoption is expected to vary with age if the new varieties are adopted for nutrition. The differences in mean of age of female spouse are also significant. Observed differences between levels of education of household heads of adopters and non-adopters are not significant. The mean education years of adopters is slightly higher than that of non-adopters. However, differences in the mean education levels of female spouses between adopters and non-adopters is significant.

The study does observe significant differences between adopters and non-adopters in the mean size of land owned. Considering that KK15 beans is promoted mainly as a nutrition crop as opposed to commercial crop, farmers grew it mainly for food in very small pieces of land. Hence adoption decision may not be affected by land size owned. Adopters had more average interaction with agricultural agents relative to non-adopters. The difference in the means is significant, implying that as expected, interaction with extension agents is associated with decision to adopt. The observed differences in the mean of the household size between adopters and non-adopters are very small and statistically insignificant.

Perception of KK15 beans

Previous studies have revealed the importance of farmer preferences and perception of the attributes of a new technology on the decision to adopt (Adesina and Baidu-Forson, 1995; Cavallo et al., 2014). It was therefore found necessary to determine the association between farmer's perceptions of the agronomic, marketability and taste attributes of KK15 variety and adoption. During analysis, the farmers were divided in to adopters and non-adopters and the characteristics analysed. Of the 661 respondents, only 422 were aware of the variety, of which 137 adopted. However, information on perception was not available for all farmers who knew of the variety. Table 2 presents results for chi square tests to determine differences in perceptions between adopters and non-adopters. The numbers of farmers are reported for each category (adopters and non-adopters), percent of farmers is shown in parenthesis.

Table 2: Farmer perceptions about KK15 Bean Variety attributes

Characteristic	Adoption status	Better	Worse	No difference	Don't know	Pearson Chi2
Maturity Period	Adopters	128 (96)	1 (1)	3 (2)	1 (1)	18.7 ***
	Non-adopters	217 (82)	2 (1)	11 (4)	36 (13)	
Yield	Adopters	122 (91)	4 (3)	5 (4)	3 (2)	15.3 ***
	Non-adopters	212 (79)	8 (3)	7 (3)	40 (15)	
Pest & disease Resistance	Adopters	90 (67)	12 (9)	24 (18)	8 (6)	33.9 ***
	Non-adopters	120 (45)	16 (6)	49 (18)	82 (31)	
Marketability	Adopters	46 (34)	44 (33)	9 (7)	35 (26)	18.1 ***
	Non-adopters	71 (27)	51 (19)	23 (9)	122 (46)	
Taste	Adopters	120 (90)	2 (1)	4 (3)	8 (6)	79.7 ***
	Non-adopters	117 (44)	10 (4)	13 (5)	127 (48)	

Notes: ∗∗∗, ∗∗, and ∗ show perceptions of KK15 bean variety adopters are significantly different from those of non-adopters at the 1%, 5%, and 10% respectively.

The results show that there are significant differences in how adopters and non-adopters perceived different attributes of the KK15 variety. As expected, more adopters relative to non-adopters perceived the KK15 variety as better in all the attributes they were asked about. Of special interest is the perception on taste; almost all the adopters perceived KK15 beans as having a superior taste to other bean varieties compared to less than half of non-adopters. It is not clear whether this perception was created before or after adoption. Regardless, if it was after, then there is likelihood that adopters would spread the information to other farmers, thereby increasing adoption.

In order to confirm that adopters perceived KK15 beans as better than existing varieties, a perception index is created using the characteristics in the table, but also including perception on price and cost of production. A t-test for the perception index by adoption status is also carried out. The result of the t-test shows that difference between adopters and non-adopters in perception index is significant at one percent.

Regression Results

Determinants of Variety Awareness and Nutrition Knowledge

Table 3 shows the results of probit regression for determinants of variety awareness and nutrition knowledge. As noted earlier, the factors that influence awareness and knowledge do not necessarily need to be similar to the ones that influence adoption.

Table 3: Determinants of KK15 Variety Awareness and Nutrition Attributes Knowledge

Variables	Variety awareness		Nutrition attributes knowledge	
	Coefficients	Marginal effects	Coefficients	Marginal effects
Distance to tarmac (Kms)	0.028*	0.009*	0.004	0.001
Group trained	1.631***	0.584***	1.038***	0.349***
No. of extension visits	0.244***	0.083***	0.113***	0.027***
Social network index	0.054**	0.018**	0.133***	0.032***
On-farm income (log)	-0.087	-0.030	-0.106	-0.026
Household head is male	-0.481***	-0.151***	-0.088	-0.021
Size of land owned	0.123*	0.042*	0.021	0.005
Age of HH head	-0.163	-0.055	0.245	0.059
Farm diversity (crop count)	0.022	0.007	-0.020	-0.005
Education of HH head	-0.008	-0.003	-0.002	0.000
Constant	-0.395		-0.810	
Number of obs	646		406	
LR chi2(10)	302.05		54.22	
Prob > chi2	0.000		0.000	
Pseudo R2	0.3576		0.1327	
Log likelihood	-271.335		-177.155	

Notes: *, **, and * denote statistical significance at the 1%, 5%, and 10% respectively.**

Distance in Kilometres to tarmac road, membership to a group that had received training, number of extension visits, social network index, gender and size of land were significant at various levels for awareness of the variety. However, only membership to a group that had received training, number of extension visits and social network index were significant for knowledge of nutrition benefits of the KK15 bean variety. It is worth noting that the three variables that are significant for nutrition knowledge relate to direct and intentional channels of transmission and reception of information.

Membership to a trained group appears to be a key driver of knowledge of nutrition benefits of KK15 beans. The variable was computed using training records of Africa Harvest. Being a member of a group that had been trained increased the likelihood of knowing the nutrition benefits of KK15 beans by 35 percentage points. The effect was higher for awareness of the variety at 58 percentage points. Contact with agricultural extension increased the probability of knowing both the variety and its nutritional benefits. Every additional contact with an extension officer increased likelihood of awareness of variety and knowledge of nutritional benefits by 8.3 percentage points and 2.7 percentage points respectively.

Only social network index had a higher effect on knowledge of nutritional benefits compared to awareness of variety. Every additional person that the farmer discussed agriculture or nutrition with increased the probability of variety awareness and nutrition benefits knowledge by 0.02 and 0.03 respectively. The effect of information dissemination on nutrition appears to be stronger between farmers than extension staff. It is not clear why this is so since extension staff who were involved in promotion of KK15 beans had also been trained on the nutritional benefits. It could be because farmers had more interaction between themselves in terms of time and content than with extension staff.

Awareness of the KK15 bean variety increases with distance from tarmac road. Although this may appear contrary to expectation, a similar result was found by Kabunga (2012); that farmers in remote areas appear to have increased awareness of new varieties. Distance to tarmac road is however not significant for knowledge of nutrition benefits of KK15 beans. Kabunga hypothesised that farmers in remote areas have fewer economic opportunities and thereby actively search out new varieties. The assumption could hold true and explains why only awareness to variety is true. It could be that due to the need to find new economic opportunities, farmers in remote areas are more interested in the economic aspects of the new varieties, as opposed to nutrition.

Gender of the household head had a significant effect on of awareness KK15 bean variety. The probability of awareness of the variety increased by 0.15 if the household head was female. Previous studies have shown that men have more control of cash crops while women have more control over food crops (Dolan, 2001). The KK15 bean variety can be deemed a food crop as it did not have superior economic benefits to other bean varieties, thus it is true to assume that it elicited more interest in women than men. Farmers who owned larger pieces of land were more likely to be aware of the KK15 bean variety. This is because farmers with larger pieces of land had probably more space to grow extra crops and thus sought out new varieties to grow.

Development organizations, government extension officers and other agriculture and nutrition dissemination organizations cannot pass information to every single individual in the society. As such, such information is expected to also pass through established channels in the society to majority of the farmers even long after development projects have ended. Hence other factors that determine information flow are important. This study shows that apart from actual training and extension, other existing socioeconomic factors also determine spread of information. These factors should be taken into consideration when designing programmes, so as to ensure the information is spread even when the projects cease to exist.

2.1.Adoption Rates of KK15 Beans Variety

The results of the ATE estimation are presented in table 4. The study estimate parameters for binary adoption variable and also for quantity of seed grown in Kgs. All estimated parameters are significant at one percent. The results based on the binary adoption variable are interpreted as percentage.

Table 4: ATE parametric estimation of population adoption rates

	Linear Models		Probit models	
	Variety awareness unconstrained	Nutrition knowledge unconstrained	Variety awareness unconstrained	Nutrition knowledge unconstrained
ATE	0.626***	0.882***	0.297***	0.381***
	(0.101)	(0.122)	(0.021)	(0.025)
ATE1	0.731***	0.949***	0.325***	0.389***
	(0.101)	(0.134)	(0.021)	(0.025)
ATE0	0.441***	0.597***	0.246***	0.346***
	(0.119)	(0.128)	(0.026)	(0.029)
JEA	0.465***	0.772***	0.208***	0.318***
	(0.065)	(0.109)	(0.014)	(0.020)
GAP	-0.162***	-0.110***	-0.089***	-0.063***
	(0.043)	(0.024)	(0.010)	(0.005)
PSB	0.104***	0.066***	0.028***	0.008***
	(0.030)	(0.025)	(0.007)	(0.003)
Observed				
Exposure rate			0.638***	0.818***
			(0.019)	(0.019)
Adoption rate			0.207***	0.317***
			(0.016)	(0.023)
Adoption rate among exposed	0.727***	0.945***	0.325***	0.387***
	(0.108)	(0.145)	(0.025)	(0.028)
mean adoption levels				
Number of obs.	640	398	661	407
Number of exposed	407	324	442	333
Number of adopters	130	125	137	129

Notes: * and ** denote statistical significance at the 1% and 5% level, respectively. Robust standard errors reported in parenthesis**

The sample variety awareness rate of KK15 beans is 64 percent, while the estimate for knowledge for nutrition benefits is 82 percent among those who knew the variety. The results show that 442 farmers were aware of the KK15 bean variety, while 333 farmers were knowledgeable of the nutrition benefits. This therefore shows that not all farmers were aware of the variety, which demonstrates incomplete diffusion of information in the population. In addition, not all the farmers aware of the variety also had knowledge of the nutrition attributes of the variety.

The observed adoption rate is 21 percent when awareness of variety is not a constraint, and 32 percent when knowledge of nutrition attributes is not a constraint. The Joint Exposure and Adoption (JEA) corresponds to the actual adoption rate at 21 percent. However, the JEA and observed adoption rates are not accurate indicators of adoption due to non-exposure bias (Diagne and Demont, 2007). The true population adoption rate corresponds to the ATE which is the predicted adoption rate after adjusting for heterogeneous information exposure.

The predicted population adoption rate (ATE) when awareness of the variety is not a constraint is 30 percent and 38 percent when knowledge of nutrition attributes is not a constraint. This shows an estimated adoption gap of 8 percent, which can be interpreted as nutrition attribute knowledge gap. The ATE as measured by quantity of seed grown was 0.6 Kg for awareness unconstrained group and 0.9 Kg for awareness and nutrition knowledge unconstrained group. It therefore follows that the average demand for KK15 bean seeds would have been 0.6 Kg if all farmers were aware of the variety and 0.9 Kg if all farmers were aware of the variety and knew the nutritional benefits. The difference (0.3 Kg or 8 percent) represents the potential (adoption) loss due to lack of knowledge of the nutritional benefits of KK15 beans.

The estimated adoption rate among the variety awareness unconstrained subpopulation ($ATE'T_r$) and variety awareness and nutrition knowledge unconstrained subpopulation ($ATE'T_k$) is 33 percent and 38 percent respectively. When measured by amount of seed grown, the estimated *ATE'Tr* and *ATE'Tk* is 0.73 and 0.95 respectively. The *ATE'Tr* is smaller than *ATE'Tk* by only 5 percentage points. The *ATE'T* is consistently higher than ATE, indicating a positive and statistically significant Population Selection Bias (PSB) for the variety aware group as well as nutrition knowledge group. The PSB for variety aware is 2.8 percent and 0.8 percent for the farmers with knowledge on KK15 nutrition benefits.

Because the PSB is positive and statistically significant for variety aware, the null hypothesis that KK15 variety aware sub-population was equally likely to adopt as the general population is therefore rejected. The implication is that the probability of adoption for farmer selected from the variety aware sub-population was different than for a farmer randomly selected from the general population. The null hypothesis that the subpopulation with nutrition knowledge on KK15 variety was equally likely to adopt the variety as the general population is also rejected. Because the PSB is positive and significant, the study concludes that a farmer selected form the subpopulation of farmers who had knowledge of the nutrition benefits of KK15 had a higher probability of adopting than a farmer randomly picked from the general population.

The potential adoption rate among farmers who had not been exposed to the variety and nutrition knowledge of the variety was 25 percent and 35 percent respectively. The KK15 variety awareness exposure gap is 9 percent, while the nutrition knowledge gap is 6 percent. The implication is there is still potential for increasing adoption of KK15 bean variety by increasing awareness of the variety and knowledge of its nutrition benefits.

2.2.Determinants of KK15 Adoption

Table 5 and 6 present results determinants of KK15 bean variety adoption among farmers in Western Kenya. Table 5 presents 4 model specifications for parametric linear regression results that are estimated using quantity of seed that a farmer grew in the previous season as dependent variable. Model 1 presents results for variety awareness unconstrained group while results for nutrition knowledge unconstrained group are presented in model 2.

Table 5: Parametric Linear Regression Results for Determinants of KK15 Adoption

	(1) Variety awareness		(2) Nutrition knowledge	
	1 (a) Classic	1 (b) ATE	2 (a) Classic	2 (b) ATE
Variables	Coefficient	Coefficient	Coefficient	Coefficient
Social Network Index	0.014*	0.022**	0.021*	0.026*
	(0.007)	(0.011)	(0.011)	(0.013)
Distance to produce market	-0.021**	-0.041**	-0.049**	-0.055**
	(0.011)	(0.018)	(0.021)	(0.024)
Wealth index	0.120*	0.204**	0.175*	0.204
	(0.062)	(0.101)	(0.105)	(0.125)
Gender of HH head	0.015	0.058	0.024	-0.057
	(0.128)	(0.188)	(0.196)	(0.243)
Size of land owned (acres)	-0.044	-0.077	0.124	0.142
	(0.070)	(0.096)	(0.200)	(0.225)
Age of HH head (years)	-0.140	-0.238*	-0.263*	-0.342*
	(0.087)	(0.136)	(0.139)	(0.181)
Farm diversity (crop count)	0.018	0.032	0.023	0.044
	(0.015)	(0.023)	(0.027)	(0.033)
Ease of acquiring credit (dummy)	0.182**	0.330**	0.369**	0.481**
	(0.091)	(0.159)	(0.177)	(0.226)
No. of extension visits	0.115***	0.094***	0.126**	0.120**
	(0.023)	(0.027)	(0.052)	(0.057)
Education of HH head	-0.001	-0.001	0.004	0.007
	(0.013)	(0.022)	(0.025)	(0.030)
Household size	-0.010	0.002	0.029	-0.033
	(0.026)	(0.043)	(0.057)	(0.070)
Number of obs.	627	401	392	318
F(9, 618)	7.47	7.91	6.86	7.05
Prob > F	0.00	0.00	0.00	0.00

Notes: *, ** and * denote statistical significance at the 1%, 5% and 10% respectively. Robust standard errors reported in parenthesis**

Table 6 similarly presents 4 model specifications for parametric probit regression results using binary adoption variable as dependent variable; ‘yes’ if farmer adopted and ‘no’ if farmer did not adopt.

Table 6: Parametric Probit Regression Results for Determinants of KK15 Adoption

	(3) Variety awareness		(4) Nutrition knowledge	
	3 (a) Classic	3 (b) ATE	4 (a) Classic	4 (b) ATE
Variables	Coefficient	Coefficient	Coefficient	Coefficient
Social Network Index	0.002	0.004	0.003	0.004
	(0.006)	(0.007)	(0.007)	(0.008)
Distance to produce market	-0.036**	-0.042**	-0.033*	-0.031*
	(0.017)	(0.018)	(0.018)	(0.018)
Wealth index	0.084*	0.122**	0.137***	0.140**
	(0.045)	(0.051)	(0.053)	(0.057)
Gender of HH head (dummy)	-0.029	0.138	0.147	0.152
	(0.148)	(0.168)	(0.173)	(0.184)
Size of land owned (acres)	-0.057	-0.093*	-0.096*	-0.095*
	(0.049)	(0.048)	(0.049)	(0.051)
Age of HH head (years)	-0.344***	-0.315***	-0.355***	-0.357***
	(0.079)	(0.085)	(0.091)	(0.103)
Farm diversity (crop count)	0.051***	0.060***	0.059***	0.086***
	(0.018)	(0.020)	(0.020)	(0.023)
Ease of acquiring credit (dummy)	-0.011	0.005	0.109	0.112
	(0.173)	(0.195)	(0.207)	(0.226)
No. of extension visits	0.121***	0.079***	0.085***	0.070***
	(0.022)	(0.020)	(0.022)	(0.023)
Education of HH head	-0.043**	-0.044**	-0.048**	-0.053**
	(0.017)	(0.020)	(0.020)	(0.022)
Household size	-0.032	-0.016	-0.019	-0.029
	(0.031)	(0.035)	(0.036)	(0.039)
Number of Obs.	645	415	400	326
Wald chi2(11)	258.3	85.35	86.37	48.11
Prob > chi2	0.00	0.00	0.00	0.00
Log likelihood	-286.13	-238.61	-225.59	-196.80

Notes: ∗∗∗, ∗∗ and ∗ denote statistical significance at the 1%, 5% and 10% respectively. Robust standard errors reported in parenthesis

The practical difference between ATE and classic regression is that ATE uses the exposed sub sample (variety awareness or nutrition knowledge) while classic model uses the full sample (Nguezet et al., 2013). The classic model, Diagne and Demont (2007) argue, yields inconsistent coefficient estimates for the model on determinants of adoption. The same is confirmed in this study as all the coefficient estimates for the classic models are smaller than those for the ATE corrected models. The results also differ in level significance, which is higher for the ATE results than the classic model for some of the variables. A few differences in significance and direction of influence are also observed between the classic and ATE model results.

Age of the household head is insignificant in the classic linear model (model 1a), but significant for ATE linear among the variety aware unconstrained group (model 1b). Also, wealth index is significant in the classic linear model (2a) and insignificant for ATE linear model (2b) for nutrition knowledge unconstrained group. Size of land owned is also significant in the ATE probit model and insignificant in the classic probit for the variety aware unconstrained group. For the purpose of this study, only ATE results will be interpreted.

Social network positively influences adoption as measured by quantity of seeds a farmer grows. The quantity of seeds that a farmer grew increased with the number of fellow farmers that they discussed agriculture and nutrition with. Social networks increase channels of receiving information and thus such farmers receive sufficient information on the variety to be able to adopt. Social network index was calculated using data that was collected just before the project started to avoid violating the conditional independence assumption discussed in section 2. Although the direction is positive, social networks doesn't appear to significantly affect the probability of adoption as shown in model 3.

Distance to produce market negatively affects the probability of adoption and quantity of KK15 beans seeds grown. Produce market in this study is defined as the market where the farmer buys or sells farm produce. It therefore implies ease or difficulty of access to seeds, or even market to sell the produce when harvested. The produce market could also be an important source of information on the new varieties. Therefore farmers who are located far away from these markets could lack both access and information on the new varieties. Previous studies have shown the importance of access for adoption to occur (Kabunga et al., 2012). Distance to market is also a proxy for transaction costs which reduce adoption.

Wealth index is significant at 1 percent for quantity of KK15 bean seeds grown for the variety aware unconstrained group but not the nutrition knowledge unconstrained group. The difference in significance is however very small as the P>chi is 0.104 for nutrition knowledge and 0.097 for variety aware. Wealth index is however highly significant for probability of adoption as shown in model 3 and 4. Age of the household head negatively influences the probability of adopting KK15 beans and also the quantity of seeds that a farmer would grow. Previous studies on adoption of new varieties bred for nutrition have found similar results, that younger farmers are more likely to adopt the relative to older farmers (Shikuku et al., 2014; Okello et al., 2014).

This could be as a result of the kind of nutrition message disseminated, and also the nutritional composition of the specific crop. Younger farmers are more likely to be in the child bearing age and also with young children. Kaguongo et al. (2010) found that presence of children less than five years of age in the households increased the intensity of adoption of orange fleshed sweet potatoes in Kenya. These farmers would likely find it more beneficial to adopt the bean varieties for nutrition purposes. As mentioned in section 1, KK15 beans have higher levels of iron and zinc, nutrients that are critical for children and women in child bearing age.

Farm diversity as measured by number of crop species that a farmer grew had a positive and significant effect on probability of adopting KK15 beans. Farmer who already grew a larger number of different crops were also more likely to adopt and grow the new variety of beans. These farmers who already grew diverse crops probably did so for nutrition and food sufficiency purposes, and therefore were willing to adopt more.

The quantity of KK15 beans grown increased with farmer's perception of ease of acquiring credit. Farmers who perceived that they could easily acquire credit grew more seeds relative to those who perceived credit services as difficult to access. These farmers who perceive access to credit as easy are either wealthy and credit worthy, or willing to take risk. Access to credit is also as a result of supply side effects. Previous study have found an association between access to credit and adoption of new varieties (Zeller et al., 1998; Matuschke et al., 2007).

Number of visits from extension officers increased the likelihood of a farmer adopting KK15 beans. Farmers who had increased interaction with extension officers were more likely to adopt the new varieties. This is expected, as these farmers are more likely to be informed of the new varieties as they are released for adoption, as well access to information on the requisite agronomic practices. Numerous studies have previously shown the positive role of extension services for adoption of new varieties (Feleke and Zegeye, 2006; Nguezet et al., 2013; Elias et al., 2013)

Education of the household head negatively affected the probability of adoption of KK15 bean varieties. This is not totally implausible. More educated farmers are expected to be aware and able to acquire alternative sources of nutrition from market sources. They are therefore not likely to grow the new variety whose only benefit is nutritional. Additionally, more educated farmers are more likely to be engaged in off-farm employment and therefore not readily available to access the information through extension officers who were targeting groups only. This could be true given that table 3 shows that more educated farmers were less likely to be aware of the variety.

3. Conclusions

Efforts to combat malnutrition have for some time now focused on the role of agriculture through farm diversity and bio-fortification. Previous research on adoption of bio fortified crops assume complete information exposure in the population fail to control for uneven awareness and knowledge of nutrition characteristics of the crops by farmers. Awareness of the new varieties and knowledge of the nutritional attributes is an important prerequisite for adoption to occur. Recent literature on adoption show that the observed adoption rates derived from sample computation and classical adoption models are not accurate when exposure to the technology is not complete in the population.

Failure to control for heterogeneous information exposure exposes the results to self-selection bias and awareness bias. The Average Treatment Effect framework is used to control for heterogeneous awareness of KK15 bean variety and knowledge of the nutrition attributes in the population. The KK 15 bean is a new variety bred that contains high levels of zinc and iron, and thus important in the fight against micro-nutrient deficiency in Kenya. This study estimates the potential adoption rates when variety awareness is unconstrained, and potential adoption rates when nutrition knowledge of the attributes is unconstrained. Determinants of awareness and adoption, as well as farmer perception of the variety are also estimated.

The results of the ATE corrected models for awareness exposure and nutrition attributes knowledge are significantly different from those of the classical models for all the variables. It thus implies that variety exposure and nutrition attribute knowledge diffusion in the population was incomplete. Failure to control for variety awareness will thus underestimate adoption rates. Further, failure to control for heterogeneous knowledge of nutrition attributes would also underestimate potential adoption rates. The results also differ in level significance, which is higher for the ATE model results than the classic model for some of the variables. Differences in significance and direction of influence are also observed between the classic and ATE model results.

The KK15 variety awareness exposure gap is 9 percent, while the nutrition knowledge gap is 6 percent. The policy implication is that there is still potential for increasing adoption of KK15 bean variety by increasing awareness of the variety and knowledge of its nutrition benefits. It is thus important to make the message delivered by extension agents more 'nutrition sensitive' so as to increase adoption of crop varieties bred for nutrition. Other factors that influenced adoption of KK15 beans include social network and distance to agricultural produce market. Other factors include age and education of the household head, contact with extension agents, and farm diversity. Policies aimed at improving adoption of need to focus on improving access to information on the varieties and their nutrition attributes.

The results underscore the importance of controlling for uneven information exposure in the population when carrying out studies on adoption. It also shows the need to differentiate awareness of new varieties from actual knowledge of the nutrition attributes of the varieties in analysis. The results reveal that a larger proportion of farmers are willing to adopt the new varieties when they have knowledge of the nutrition attributes.

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