The Role of Varietal Attributes on Adoption of Improved Seed Varieties. The Case of Sorghum in Kenya

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Abstract

This paper examines the effect of variety attributes on adoption of improved sorghum varieties in Kenya. Using data from 140 farmers, the paper uses a multivariate probit to identify variety-specific drivers of adoption. The results on the perception of farmers variety attributes show that improved varieties had desirable production and marketing attributes while the local varieties were perceived to have the best consumption attributes. Evidence further indicates that the major sorghum variety attributes driving rapid adoption are taste, drought tolerance, yield, ease of cooking and the variety's ability to fetch a price premium. Early maturity, a major focus of research has no effect on adoption. The findings of the study imply that, while developing improved seed varieties, breeders should also focus on non yield attributes like taste and ease of cooking. Secondly, it is important that both producers and consumers of sorghum be involved in the seed evaluation process.

Keywords; Sorghum, Variety Attributes, Multi Variate Probit Model, Adoption

1. Background

Sorghum *(Sorghum Bicolor L. Moench)* is one of the main staple crops for the world's poorest and food insecure people. It is the second major crop (after maize) across all ecologies in Africa and is one of the main staples for people in Eastern and Southern Africa (ESA). Sorghum is a dual purpose crop where both grain and stover are highly valued outputs. Globally, sorghum is grown in 46 million hectares accounting for an annual production of 60 million tones (ECARSAM, 2005). Developing countries account for 90 percent of total area and 70 percent of total output, with Africa and Asia each accounting for 20-30 percent of the global production. Production in Africa is characterized by low productivity and extensive, low input cultivation, with limited use of fertilizer and improved seeds (FAO and ICRISAT, 1996). This is because they are mainly cultivated by small-scale resource-poor farmers in the region and yields are generally low (ECARSAM, 2007). In Kenya, sorghum is an important traditional food crops in the dry land areas of Nyanza, Eastern and Coast provinces. Averagely, the crop occupies and an area of 139,000 hectares with an annual production of 110,000 tons (FAOSTAT, 2007). The country's percapita sorghum consumption is approximately 3.0 kg per year.

Despite the numerous benefits of sorghum, its production in Kenya has remained heavily constrained by diseases, insect pest damages and rainfall variability. In response to these constrains, national and international research organizations have developed and released several high-yielding and stress tolerant varieties of sorghum with desirable agronomic and market traits. The development of improved sorghum varieties in Kenya started in early 1970s' and by the year 2005, at least seven varieties had been released in the country (ICRISAT, 2006). They include; Gadam, Serena, Seredo, KARI Mtama 1, KARI Mtama 3, IS76#23 and KAK 7780. The release of the varieties was followed by an intensive promotion programme by the Ministry of Agriculture under the orphan crop multiplication programme and the Eastern province horticulture and traditional food crops project. Reports indicate that the adoption of the sorghum varieties has been good both in the medium and marginal low potential areas of the province (Kenya Food Security Steering Group, 2008).

Although technology adoption remains one of the most researched areas in agricultural economics, very few studies (Okuthe, *et al.*, 2000; Monyo, *et al*., 2002; Nega, 2003; Mafuru, *et al*., 2007) have looked at the adoption of improved sorghum varieties. Further, the existing studies have focused on the role of socio economic, institutional and policy factors in explaining the adoption of improved sorghum varieties. This paper distinguishes itself by providing a greater insight into sorghum studies by focusing on the effect of variety attributes on adoption.

Another motivation for this study is that, many previous adoption studies have only focused on one improved variety (e.g., Nkonya et al. 1997; Zavale et al. 2005; Salasya et al. 2007) by using the conventional logit or probit approach. However, in the present study, more than one improved varieties exist each with varying production, consumption and marketing traits and farmers are more likely to simultaneously adopt more than one variety in order to address their multiple needs. We use a multivariate probit regression which allows estimation of several correlation binary choices jointly (Greene, 2003). The multi variate probit model takes into account the potential interdependence in technology choice and the possible correlation in the adoption of alternative improved varieties. The probability of adoption of any particular sorghum variety is estimated conditional on the choice of any other related variety.

This paper is based on data collected from a stratified random sample of 140 sorghum farmers in Mbeere South County of Kenya. Mbeere South County is in an ASAL area of Kenya and sorghum is mainly grown as a food crop to edge farmers against the risk of crop failure. The rest of the paper is organized as follows. Section two presents the methods and the variables used in the empirical analysis while section three reports and discusses the results. Section four concludes.

2.0 Theoretical and Empirical Methods

2.1 Theoretical Framework

The theoretical framework draws from the theory of agricultural households. Following Edmeades (2003), variety consumption attributes are incorporated into the utility function. In the consumer theory, the utility derived from the consumption of a good is specified as a function of the intrinsic attributes supplied by the good rather than the good itself. The specification of intrinsic properties of a variety as arguments of a utility function and application of an agricultural household model allows for the inclusion of variety consumption attributes in the econometric estimation of the variety adoption (Katungi, 2011). Following these, the agricultural household is assumed to maximize utility derived from the intrinsic consumption attributes of sorghum embodied in vector (φ^c), the purchased good (G) and home time (h). The household chooses the amount of sorghum to consume from different varieties it produces (v), the purchased good and home time subject to income (W), production technology (Q), and time endowment (T). Utility is maximized given the household preferences, which, in turn, depend on the socioeconomic characteristics of the household (Φ_{HH}) and market conditions (Φ_M). The theoretical model can be expressed as:

$$Max\ U(x(\varphi^c), G, h|\Phi_{HH}\Phi_M \quad (1)$$
$$Q = f(v(\varphi^p), l|\Phi_F\Phi_M$$
$$T - L - H = 0$$
$$\sum_{i=l}^{k} v_i = 1$$
$$x_i \geq 0, q_i, v_i \geq 0$$

The total amount of sorghum consumed (x) can be distinguished according to the intrinsic and extrinsic attributes of sorghum varieties such as taste, cooking time and grain colour (φ^c) they possess. The amount consumed of each variety can vary across households but the levels of intrinsic properties each possesses are fixed from the perspective of the household. Full income in a single decision making period is composed of the net farm earnings (profits) from crop production and income that is exogenous to the season's crop such as stocks carried over, remittances, pension and other transfers from the previous season. For goods that are not traded, the prices that govern the choices of the household are endogenous to the household, determined by internal supply and demand for the good, expressing the household's valuation of the good.

The production technology constraint establishes the output-input technical relationships and the production margins. Sorghum in the study area is produced by combining labour and seed of specific varieties on land that is fixed in a single cropping season. The choice and allocation of the sorghum area to a specific variety is influenced by the decision maker's perception of the variety agronomic attributes such as maturity period, drought resistance, yield, pest tolerance, expressed in vector, $v(\varphi)$. The demand for variety specific agronomic attributes emanates from the need for farmers to maximize returns from production as well as stabilize income from sorghum. The land constraint circumscribes the land area allocated to sorghum, the household can choose to allocate all sorghum area to one variety or simultaneously plant multiple varieties if certain attributes are unique to a particular variety. Varieties planted can vary across households. The vector (Φ_F) denotes farm characteristics. The time constraint captures the total time available to production and home activities. The vector of market condition (Φ_M) captures the role of market imperfections in variety demand.
Kuhn-Tucker conditions are used to derive optimal demand of varieties. Given that the conditions are met, the following reduced form equation defines the optimal share of sorghum area allocated to variety i.

$$v_i^* = v(\varphi^C, \varphi^p, p_a, p_g, I, \Phi_{HH}, \Phi_F, \Phi_M), \qquad (2)$$

Equation 2 can be treated as the adoption equation. Adoption of variety i is derived as a function of variety consumption and production attributes $(\varphi^c \varphi^p)$, the socio-demographic characteristics of the household $(\boldsymbol{\Phi_{HH}})$ and characteristics of the farm (Φ_F) and market characteristics(P_a, P_g, Φ_M).

2.2 Empirical Model

A multivariate probit is used to analyze the effect of varietal characteristics on adoption of improved sorghum varieties. A multivariate probit has been used previously in a number of adoption studies (Gedikoglu and MacCann, 2007; Marenya and Barrett, 2007; Otieno, 2010), the model accounts for simultaneous adoption of multiple varieties and the potential correlations among the adoption decisions. The multivariate probit is an extension of the probit model (Greene, 2003) and is used to estimate several correlated binary outcomes jointly.

The model is specified as follows;

$$Y_{im}^{*} = \beta_m X_{im} + \varepsilon_{im} \qquad (3)$$

Where $Y_{im}^{*}(m = 1, \dots, k)$ represent the unobserved latent variable of improved sorghum varieties adopted by the i^{th} farmer$(i = 1, \dots, n)$. Out of the seven improved varieties released to farmers in the study area, only two varieties were widely adopted (Gadam and Serena), very few farmers had adopted Seredo and KARI Mtama 1 while no farmer had adopted KARI Mtama3, IS76#23 and KAK 7780. Therefore, the analysis was limited to only two improved varieties; Kimbeere variety (the most common local variety) was also included in the analysis for comparison purposes. Therefore, in this case k= *Serena, Gadam and Kimbeere*. X_{im} is a $\mathbf{1} \times \boldsymbol{k}$ vector of observed variables that affect the variety adoption decision, the variables include household socioeconomic, institutional factors and variety attributes. β_m is a $\boldsymbol{k} \times \mathbf{1}$ vector of unknown parameters to be estimated. $\varepsilon_{im}, m = 1, \dots, M,$ are the error terms distributed as multivariate normal, each with a mean of zero, and variance–covariance matrix V , where V has values of 1 on the leading diagonal and correlations (Cappellari and Jenkins, 2003).

Equation (3) is a system of m equations that as shown in equation 4 below;

$$\left\{\begin{array}{l} Y_1^{*} = X_1\beta_1 + \varepsilon_1 \quad Y_1 = 1 \ \textit{if}\ Y_1^{*} \succ 0, \ Y_1 = 0 \ \textit{otherwise} \\ Y_2^{*} = X_2\beta_2 + \varepsilon_2 \quad Y_2 = 1 \ \textit{if}\ Y_2^{*} \succ 0, \ Y_2 = 0 \ \textit{otherwise} \\ Y_3^{*} = X_3\beta_3 + \varepsilon_3 \quad Y_3 = 1 \ \textit{if}\ Y_3^{*} \succ 0, \ Y_3 = 0 \ \textit{otherwise} \end{array}\right\} \qquad (4)$$

This system of equations is jointly estimated using maximum likelihood method.

The implicit functional form of the empirical model is specified as follows;

Decision to adopt= *f* **(**age, gender, education, farming experience, household size, farm size, off farm income, distance to the market, extension visits, non livestock asset value, group membership, yield, drought tolerance, pest resistance, maturity, farm gate price, cooking qualities, striga resistance, brewing qualities and taste) +ε.

3. Results and Discussion

A simple descriptive analysis was conducted to identify the socio economic conditions of the farm households (Table 1). The results indicate that about 84 percent of the sampled households were male headed while the average year of formal education for the entire population is 7 years. The average household size of the total population is 4.7 persons which is slightly below the Kenya's national mean figure of 5 members per household (CBS, 2005). The mean age of adopters was 49 while for non adopters was 56. The mean farm size of adopters was 5.9 acres as compared to 3.9 acres for non-adopters. The mean value of all livestock assets was Kshs 43,000 and Kshs 41,000 for adopters and non adopters respectively. On the other hand, the approximately value of non livestock assets was Kshs 96,000 and Kshs 86,000 for adopters and non-adopters respectively.

Distances to the nearest market and nearest all weather roads were used as proxies for market access. On average, adopters had better access to market (5.3 Km) than the non adopters (6.7 Km). Similarly, the distance to the nearest extension agent was used as a proxy for information access. The average distance to the nearest extension agent was 4 Km and 5.5 Km for the adopters and non adopters respectively. On average, 61 percent of adopters were members of farmers' organizations. Farmer organizations also act as conduits for information sharing hence the high rate of adoption. Only 42 percent of the non adopters belonged to farmer organizations.

3.1 Drivers of Variety Adoption

The multi variate probit system was estimated jointly for three dependent variables; Gadam, Serena and Kimbeere. The results of the analysis are presented in Table 2 below. The p-value of the Wald test statistics for the overall significance of the regression is very low (0.0001) indicating that the multi variate regression is highly significant. Further, the likelihood ratio test of rho is highly significant (p-value=0.000) indicating that a multivariate probit specification fits the data.

Another important result is that the correlation coefficients among the error terms are significant indicating that the decision to adopt one variety affects the decision to adopt the other (Table 3). The correlation coefficient between the two improved sorghum varieties is positive and significant at 1 percent. On the other hand, the correlation coefficients between the local Kimbeere variety and the two improved variety are both negative and significant at 5 per cent level. These results point to the cross-equation correlation of the error terms and hence interdependence in the adoption of improved varieties. This also indicates that farmers who adopt one improved sorghum variety are also likely to adopt another. These diagnostic tests further support the use of multivariate probit regression and indicate that use of simple probit will result in inconsistent estimates.

3.1.1 Effect of Variety Attributes on Adoption of Gadam variety

The results presented in Table 2 show that farmers adopted the Gadam variety because of its desirable attributes in terms of yields, pest resistance, brewing qualities, ease of cooking and ability to yield a price premium. Price was positive and significant at 1 percent level, whereas ease of cooking, yield, and brewing quality were positively significant at 5 percent level. Pest resistance trait was also positive and statistically significant at 10 percent. The marginal effects results show that the variety attributes had the greatest effect on the probability of adoption. For instance, if the farmer perceives the variety's pest resistance, yield and ease of cooking to be good, the probability of adoption will increase by 0.7, 0.5 and 0.4 percent respectively. Contrary to our expectations, early maturity trait does not significantly influence the farmers' decision to adopt.

Among the socio economic factors; age, education and household size had statistically significant coefficients. The negative coefficient of age implies that the probability of adopting Gadam variety decreases with an increase in the age of the farmer. This could be explained that, older people are less receptive to new technologies and are not willing to take risks. The results of the marginal effects imply that a 10 percent increase in age will lead to a 5 percent decrease in the probability of adoption. The coefficient for education is positive and statistically significant at 5 percent level. As expected, well educated producers have the human capital to more fully understand and utilize information than those without management expertise (Mishra and El-Osta, 2002). The results also suggest that the likelihood of adoption increases with increase in the household size. This implies that bigger households provide the required farm labour associated with the use of new technology.

The value of non livestock assets, farm size and distance to the market are all significant. The coefficient of the value of non livestock assets was positive and statistically significant at 5 percent level. The findings imply that asset ownership promotes adoption and continued use of improved seeds since it improves the farmers ability to finance the purchase of inputs associated with improved technology. The results also suggest the likelihood of adopting Gadam variety increases with increase in farm size. As expected, a larger farm size allows one to experiment with new crop varieties and even practice crop diversification in order to hedge against the risk of crop failure. The coefficient of the number of extension visits was positive and statistically significant at 1 percent level. The positive effect of extension shows the role that proactive extension can still play in accelerating technological change in smallholder agriculture in Africa. The finding that extension enhances the adoption of improved agricultural technology corroborates those of (Nzuma, 2000; and Alene and Manyong, 2007).

A joint hypothesis test on the effect of variety attributes on the adoption of Gadam was conducted. The p value of the Wald test was 0.0012. Therefore the null hypothesis was rejected at 1 percent level. These results indicate that variety attributes affect the farmers' decision to adopt improved varieties.

3.1.2 Effects of Variety Attributes on the Adoption of Serena Variety

Serena is the most popular improved variety in the study area. The multi variate probit results show that among the varietal attributes considered, yield, pest resistance and ease of cooking significantly influenced the probability of adopting Serena variety. Yield and ease of cooking variety traits were statistically significant at 5 percent level whereas pest resistance trait was significant at 1 percent. The results of the marginal effects further suggest that if a farmer perceives the yield attribute as being good, the likelihood of adopting Serena variety increases by 0.34 percent, whereas a similar perception on ease of cooking and pest resistance traits is expected to increase the probability of adoption by 0.33 and 0.56 respectively. These results suggest that the popularity and widespread adoption of Serena variety was driven by its desirable attributes in terms production and consumption.

Among the socio economic factors, only off farm income affected the likelihood of adopting Serena variety. A 10 percent increase in off farm income increases the probability of adopting Serena by 2 percent. The results agrees with the previous findings in this study on the role of income obtained from such activities in purchasing farm inputs such as improved seeds, fertilizer and pesticides . The number of extension visits was also significant at 10 percent. This further reaffirms the importance of extension visits in exposing farmers to improved technology.

The p value of the Wald test on the effect of variety attributes was 0.000. These results imply that we reject the null hypothesis at 1 percent level.

3.1.3 Effect of Variety Attributes on the Adoption of Kimbeere Variety

The coefficients of taste and pest resistance traits were positive and statistically significant at 10 percent level while that for drought tolerance was significant at 5 percent level. The coefficient for yield and ease of cooking are both negative and statistically significant at 5 and 10 percent levels respectively. These results imply that the farmers preferred the local Kimbeere variety partly because of its desirable attributes in terms of production and consumption.

Among the socio economic variables, household size was statistically significant at 1percent level. The results also indicate that a 1 percent increase in household size will increase the probability of adoption by 0.4 percent. Group membership was also found to affect the adoption of Kimbeere variety. This variable was negative and statistically significant at 5 percent level. The results of the marginal effects show that a 10 percent increase in the number of farmers belonging to a group decreases the likelihood of adoption by 2 percent. This finding implies that group membership reduces the likelihood of adoption of local varieties. Indeed, groups enhance sharing of information among farmers. As such, farmers may share information on new seed varieties and even pool their meager resources in order to purchase farm inputs such as fertilizer which would have otherwise been expensive on an individual basis. Similar results were reported by Katungi *et al.,* 2007. Similarly, the number of extension visits had a negative and statistically significant coefficient. The inverse relationship between the number of extension visits and adoption of Kimbeere variety could probably be due to too much focus on improved varieties and neglect of traditional varieties.

The p value of the Wald test of the joint hypothesis test on the effect of variety attributes on adoption of Kimbeere is 0.0176. From the findings, we reject the null hypothesis that variety attributes have no effect on adoption at 5 percent level.

4. Conclusion and Recommendation

This paper analyses the factors affecting adoption of improved sorghum varieties in Kenya using a multi variate probit. The results indicate that the variety adoption choices are correlated implying that joint estimation is appropriate and single probit/logit specifications would yield inefficient standard errors. The results show that variety specific attributes (yield, pest resistance, ease of cooking, ability to yield a price premium, taste and brewing quality), farmer specific factors (age and education), institutional factors (extension visits and group membership) and endowment with physical and financial assets are the key drivers of adoption of improved sorghum varieties. However the magnitude of effect varies across different varieties. Contrary to our expectations, it was also found that early maturity trait did not appear to influence the adoption of improved seed varieties.

In developing improved seed varieties, breeders should also focus on non-yield attributes for instance taste, brewing qualities and ease of cooking. Secondly, it is important that producers, processors and consumers of sorghum be involved in seed evaluation processes. This will ensure that both production and consumption attributes of improved seeds are well evaluated and accepted by the targeted end users before disseminating the varieties to the market. Finally, policies that enhance adoption of improved seeds should also be enacted. These include; investment in education and providing extension services to the farmers.

List of Abbreviations

ASALs-Arid and Semi Arid Lands

CBS-Central Bureau of Statistics

ECARSAM- Eastern and Central Africa Regional Sorghum and Millet Network

ESA - Eastern and Southern Africa

ICRISAT- International Crops Research Institute for the Semi-Arid Tropics

FAO- Food and Agriculture Organization

KARI- Kenya Agricultural Research Institute

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Table 1; Means of Socioeconomic Variables of the Surveyed Households

	Total	Adopters		Non adopters	
Socio-economic indicators	***Mean***	***Mean***	***Std. Deviatio***	***Mean***	***Std. Deviation***
Distance to the nearest market (Km)		4.81	3.82	6.72	4.40
Distance to the nearest tarmac road (Km)	8.0	7.59	4.37	9.42	5.48
Distance to the nearest agricultural extension agent (Km)	4.4	4.05	3.24	5.58	3.36
Household size (Count)	4.7	5.02	2.33	3.66	1.66
Farm size (Ha)	4.8	5.11	6.44	3.88	2.28
Livestock value (1000 Kshs)	42.84	43.34	46.81	41.28	44.07
Extension visits (Count)	1.8	2.10	1.70	1.00	1.48
Assets (1000 Kshs)	94.1	96.70	110.96	86.33	104.40
Off farm income (1000 Kshs)	125.65	128.75	1765.92	123.10	154.36
Age of farmer (Years)	51.0	49.33	15.12	56.03	14.36
Highest education grade completed (Years)	7.4	7.60	3.67	6.66	4.01
Farming experience in years (Years)	23.1	22.23	14.60	25.69	15.76

Table 2; Results of the Wald test of simultaneity of the decision to adopt different Sorghum Varieties

	Coefficient	**P-value**
/atrho21	0.202	0.004
/atrho31	-0.226	0.032
/atrho32	-0.318	0.029
rho21	0.199	0.047
rho31	-0.222	0.031

Table 3; Factors Affecting Adoption of Improved Sorghum Varieties: Results of Multivariate Probit regression

	Gadam			Serena			Kimbeere		
	Coefficient	**P-value**	**Marginal Effect**	**Coefficient**	**P-value**	**Marginal Effect**	**Coefficient**	**P-value**	**Marginal Effect**
Yield	0.559	0.021**	0.462	0.239	0.021**	0.335	-1.109	0.028**	-0.261
Drought resistance	0.580	0.247	0.146	0.980	0.698	0.201	0.967	0.040**	0.310
Striga	0.093	0.247	0.022	0.573	0.459	0.230	-0.283	0.534	-0.106
Maturity	-0.705	0.103	-0.203	0.744	0.413	0.242	0.499	0.199	0.192
Pest resistance	1.067	0.084*	0.674	1.757	0.001***	0.564	0.903	0.072*	0.330
Price	2.371	0.000***	0.118	1.065	0.154	0.354	0.116	0.801	0.027
Ease of cooking	1.182	0.019**	0.329	0.755	0.017**	0.332	-0.810	0.097*	-0.293
Taste	0.372	0.433	0.118	-0.330	0.645	-0.145	0.801	0.059*	0.283
Brewing quality	0.259	0.048**	0.065	1.201	0.124	0.354	0.204	0.520	0.052
Distance to the market	-0.159	0.001***	-0.052	-0.012	0.832	-0.005	0.051	0.448	0.011
Household size	0.121	0.096*	0.039	0.132	0.223	0.050	-0.136	0.001***	-0.420
Farm size	0.620	0.019**	0.189	0.183	0.616	0.041	-0.047	0.849	-0.030
Lnvalue of livestock assets	0.177	0.138	0.055	-0.275	0.126	-0.105	0.070	0.551	0.025
Extension visits	0.335	0.003***	0.113	0.085	0.053*	0.223	-0.084	0.038**	-0.260
Lnoff farm Income	0.664	0.006***	0.223	0.319	0.028**	0.127	0.285	0.146	0.106
Group membership	-0.440	0.194	-0.151	-0.049	0.906	-0.018	-0.389	0.021**	-0.136
Lnassets	0.047	0.076**	0.330	0.284	0.151	0.598	0.008	0.954	0.008
Lnage	-1.748	0.020**	-0.484	-1.056	0.285	-0.331	0.618	0.380	0.200
Gender	0.357	0.459	0.099	-0.766	0.318	-0.351	-0.137	0.749	-0.043
Education	0.034	0.024**	0.011	-0.173	0.165	-0.063	-0.038	0.491	-0.008
Farming experience	0.018	0.751	0.005	0.014	0.415	0.004	-0.008	0.537	-0.003
Constant	14.529	0.001		-0.616	0.901		-7.246	0.053	

Likelihood ratio test of rho21= rho31 = rho32 = 0 chi2 (3) = 3.28304 Prob > chi2 = 0.0000

Wald chi2(63) = 113.41 Prob > chi2 = 0.0001 Log likelihood = -128.64298