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Adoption and utilization of business innovations of agricultural research in Uganda: Empirical analysis

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This paper seeks to examine the adoption of business innovations within the context of the agricultural sector in Uganda. The findings emerge from research carried out to assess the utilization of business innovations of research in Uganda considering National Agricultural Research Organization (NARO) as a reference, specifically to find out the association between innovation attributes and their use on-farm, as well as establish the consequence of innovation features and demand (market) about the use of discoveries in farm management. The opinions of 99 participants involved in production of major crops in the Kanungu district where the NARO innovations were verified were sought. The information was assembled and scrutinized with SPSS and STATA. The findings revealed that innovation features played an important role on the extent of application of the technology. Similarly, how old participants were had a negative linkage with the use of technologies, while the extent of education helps the application of technologies by farmers.

Key words: Complexity, compatibility, relative advantage, attributes, quality, utilization, innovations, market.

INTRODUCTION

In agribusiness, innovations are normally created by experimentation, and their adoption could lead to continuous agricultural growth. The National Agricultural Research Organization (NARO), was formed as a corporate structure by the National Agricultural Research Act of 2005 to oversee all enterprises involved in experimentation in the country. The organization focus is to initiate and popularize uptake of technologies that improve the welfare of its clients. The creation of new ideas can spur growth and innovators search for improved options that provide end-users with better choices in agricultural research.

Researchers came up with theories about innovations, which influence the innovations approval and application on the outcomes of agricultural research. One of the theories highlighted by Hayami and Ruttan (1985) associates the advent of innovations with economic challenges. For example, lack of labor could be a motivation for venturing in technologies which decrease labor costs. Olmstead and Rhode (1993) pointed out that the presence of technical information, existence of starter materials and the interplay between technology users and

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creators of starter materials influence the appearance of technologies.

According to Davis (1989), the technology acceptance model has two major parts. One is what is referred to as perceived usefulness where the user believes that utilization of a system will improve the outcome. The other is the perceived ease of use where the user expects the target system to consume less energy. However, the benefits of the technology and ease of application has an effect on uptake of technology (Venkatesh and Davis, 2000). On the other hand, other factors such as how relevant the job is, the quality of output, effectiveness of result demonstration, how the performance meets expectations, influence of the community, and conducive environment affect perceived usefulness.

For an individual to adopt or utilize an innovation, it is based on the information available and the individual's capacity to compare the characteristics of innovations. Rogers (2003) highlighted innovation attributes that influence the speed of uptake of innovations.

The 'relative advantage' of a technology can be assessed by considering economic gains, initial cost, difficulty to use, and effort applied to utilize the innovation. For example, from studies where different practices are blended to reduce on pest injury, the benefits and reduced costs of production affected farmers' choice to adopt an innovation (Joo and Kim, 2004; Miller and Meek, 2004; Liao and Lu, 2008). Similarly, if an innovation can be compatible with community customs and other customer needs, it will improve innovation adoption. On the other hand, innovations that are not in tandem with user's desires and cultural norms, are not bound to be taken up faster as those that are agreeable to end users. Sarel and Marmorstein (2003) found out that there is a highly significant association between agreeable technologies and understanding how the technologies are applied. If a technology is in agreement with an individual's desires, then the prospects of adoption will rise. Therefore for new innovations, 'compatibility' is an important element of the system.

The 'complexity' of innovation implies that the innovation is not easy to comprehend or apply by clients (Rogers, 2003). The easier the new ideas are understood by end-users, the quicker the adoption of innovations compared to those innovations that require the application and development of novel ideas. An easy technology leads to a higher utilization rate and the reverse is true (Rogers, 2003; Sarel and Marmorstein, 2003).

'Trialability' can be explained by the extent to which an innovation is tested at a relatively low level (Rogers, 2003). Rogers (2003) argues that 'latent adopters', who try out innovations, find it easier to use the innovations. Furthermore, according to Kolodinsky et al. (2004), when farmers test an innovation, it increases uptake of innovation.

The assimilation of new technologies increases output and results in social advancement (Kariyasa and Dewi, 2013). In agribusiness, changes have been observed in the use of superior crop types, quality farming methods, boosting soil nutrients, pest reduction, and provision and management of water (Loevinsohn et al., 2013). Additionally, mechanization, value addition, reducing crop losses after harvest are among the technologies that increase agricultural products. In agricultural research, adoption can be measured by 'estimating the proportion of farmers using innovation or considering the areas under the innovation' (CIMMYT, 1993). Other factors that influence the adoption of innovations in agricultural systems include farmer resources and farmer characteristics, farming system, market and information (Guerin and Guerin, 1994; Hall and Khan, 2003; Ndjeunga et al., 2008).

In Uganda, NARO generated research technologies (NARO, 2018) whose uptake is moderate. There are few farmers (10%) planting superior seeds (UBOS, 2011). Similarly, there was low adoption of banana hybrids due to the fact that end-users prioritized consumer attributes such as the quality of cooked food (Akankwasa et al., 2016) irrespective of other good attributes of the products. Most studies available on adoption or utilization of technologies were done on farmer characteristics with little information on innovation and market attributes. Availability of this information will assist the generators of innovations to develop innovations that would be easily adopted hence increasing productivity and thus enhancing agricultural growth. The study sought:

1. To find out the linkage between innovation attributes and their use at farm level.
2. To demonstrate the effect of innovation aspects and demand (market) on use of innovations in agriculture.

Conceptual framework

The conceptual framework draws upon the works of several authors such as Hall and Khan (2003) and Rogers (2003). Their work has been adapted to the business innovations environment in agriculture research in Uganda. In the context of this study, innovation characteristics (relative advantage, compatibility, trialability, complexity, quality) and market conditions (demand for innovation, market share and profitability) were considered independent variables while utilization of innovations (percentage use and percent coverage) were taken as a dependent variable Figure 1).

MATERIALS AND METHODS

The survey design considered a cross-section of the population. The design was preferred because it permitted the investigator ' to

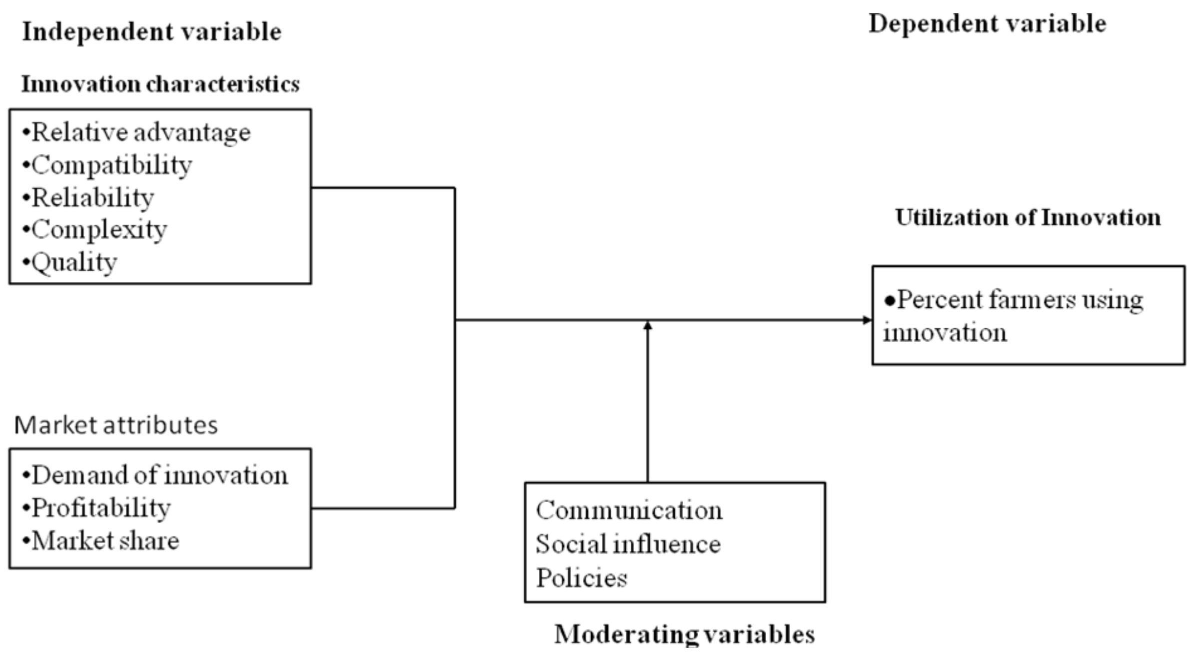

Figure 1. Conceptual framework of independent variables (innovation characteristics) and dependent variable (utilization of innovations).
Source: Adapted from Hall and Khan (2003) and Rogers (2003).

examine the parameters under study at a given point in time' (Hashem et al., 2022). It also helps to reduce bias because the sample was taken from the whole population.

At the sub-county level (the smallest administrative unit of government under a decentralized system of governance in Uganda), the villages which predominantly grow rice, cassava and maize were purposively selected. The actual households interviewed were chosen by chance. The questionnaires were used to assemble data from the participants. The questionnaires made provision for scoring technologies on a range of 1 to 5 with 1 (strongly disagree) and 5 (strongly agree) while for utilization levels 1 represented very low and 5 represented very high. Using a pre-tested questionnaire, enumerators collected data from the respondents. The data were analyzed using SPSS statistical package and STATA, and the statistics of concern such as frequencies and regressions were presented. In order to find out the linkage between innovation attributes and their use at farm level, the significance was tested at 5% using chi-square as well as using regression analysis; also the effect of innovation aspects and demand (market) on use of innovations in agribusiness was tested with an ordered logistic regression model at a 5% probability level.

RESULTS

Association between innovation attributes and their use at the farm level

Table 1 shows the level of use by commodity of respondents in Kihihi sub-county, Kanungu district. It should be noted that out of 1899 observations, the level of use of commodities varied mainly from low to moderate. For example, 655 observations and 634 observations constituted low and moderate levels of use respectively. A very low proportion of observations (133) used the commodities at a very high level. On the other hand, the level of use of commodities was very low (234 observations) with rice having the highest number of observations of 103. From the results, innovations were more highly applied in maize than in the other two commodities and the relationship between commodity and level of use was highly significant.

From Table 2, the results indicated that all three commodities had new crop type as one of the technologies. The results show a statistically significant positive association between the crops and technology characteristics. The features of compatibility, trialability and relative advantage were very important considerations.

From Table 3, the information in the regression model used accounts for 71% of the observations in the parameters studied. From the data analysed, gender and education level of respondents and all innovation attributes except complexity had a statistically strong association with the level of use of innovations for a given commodity.

From Table 4, among the parameters of relative advantage, economic feasibility has an influence on level of use of an innovation. Out of 493 observations, 80 and 68 respondents indicated that economic returns from an innovation affects the level of use of an innovation to the level of very high and high respectively. Also from the same total number of observations, respondents

Table 1. Extent of use of crop innovations by interviewees in Kanungu district, Uganda.

Crop	Level of use					
	Very low	Low	Moderate	High	Very high	Total
Cassava	89	241	196	87	44	657
Maize	42	234	273	67	63	676
Rice	103	180	165	91	26	565
Total	234	655	634	245	133	1,899
Pearson chi^2 (15)	234.0134					
Pr	0.000					

Table 2. Association of innovation attribute and uptake of crop varieties for different crop commodities in Kanungu district, Uganda.

Crop	Compatibility	Relative advantage	Complexity	Trialability	Quality	Total
Cassava	372	132	36	108	NIL	648
Maize	348	60	24	144	144	720
Rice	372	120	12	120	NIL	624
Total	1,092	312	72	372	144	1,992

$chi^2(21)$ = 2.5e+03; Pr = 0.000.

Table 3. Regression coefficients of innovation attributes with the level of utilization of commodities.

Source	Sum of squares (SS)	Degrees of freedom (df)	Mean squares (MS)
Model	547.41656	10	54.741656
Residual	2717.13291	2051	1.32478445
Total	3264.54947	2061	1.58396384
Number of obs	2062		
F (10, 2051)	41.32		
Prob>F	0.0000		
R-squared	0. 6771		
Adj R-squared	0.7136		
Root MSE	1.151		

Utilization attribute	Coef.	Std. err.	T	P>t	[95% Conf.	Interval]
Gender	.1365483	.0538004	2.54	0.011	.0310393	.2420574
Age	-.03589	.0217804	-1.65	0.100	-.078604	.006824
Education	.0617118	.0257539	2.40	0.017	.0112053	.1122183
Commodity	-.2437981	.032519	-7.50	0.000	-.3075718	-.1800243
market attribute	-.0478834	.0263708	-1.82	0.070	-.0995998	.003833
relative advantage	2.384769	.5804827	4.11	0.000	1.246372	3.523166
Compatibility	1.905091	.5795687	3.29	0.001	.7684867	3.041696
Trialability	1.024452	.5846841	1.75	0.080	-.1221842	2.171089
Complexity	-1.042043	.5813884	1.79	0.073	-.0981298	2.182217
Quality	1.807705	.5847275	3.09	0.002	.6609832	2.954426
_cons	.9673114	.590062	1.64	0.101	-.1898718	2.124495

indicated that low initial cost of an innovation influenced the level of use from a low (67) to moderate (64) level.

Soil type influences uptake of NARO innovations moderately (130 out of 833 total observations) especially new crop varieties. Climate change as well as the level of risk also affects level of use of agricultural innovations

Table 4. Effect of relative advantage parameters on frequency of level of use of innovations.

Variable	Level of use					
	Very low	**Low**	**Moderate**	**High**	**Very high**	**Total**
Feasibility	2	3	11	68	80	166
Low initial cost	6	67	64	24	4	165
Easiness to use discomfort	18	64	66	14		162
Total	26	134	141	106	84	493

Table 5. Variables of compatibility on occurrence of level of use of an innovation.

Variable	**Level of use`**					
	Very low	**Low**	**Moderate**	**High**	**Very high**	**Total**
Labor	4	37	94	27	2	164
Cropping system	38	31	70	23	2	164
Soil type	3	19	130	8	4	164
Climate	1	42	101	18	2	164
Risk	12	122	25	4	14	177
Total	58	251	420	80	24	833

Table 6. Effect of parameters of complexity on frequency of application of innovations.

Parameter	**Level of use**					
	Very low	**Low**	**Moderate**	**High**	**Very high**	**Total**
Difficult to understand	13	108	34	5	2	162
Difficult to use	48	67	13	2	2	132
Total	61	175	47	7	4	294

(Table 5).

The findings from Table 6 about the ‘complexity’ of the innovation indicate that the difficulty to understand an innovation influenced the level of application of technologies to a low level with 108 views of agreement out of a total of 294 observations. Similarly, difficulty to use also led to very low and low levels of use of innovations with 48 and 67 observations, respectively.

The mixed effects model combines the effects of different predictor variables. The probability of 0.000 shows that the model is fit and thus the combined effects of the variables have an overall statistically significant effect on the response variable (innovation utilization). If all the factors are held constant, there is a 3.37 unit change in the innovation utilization which is brought about by residuals/random effects/extraneous variables (variables not observed in the model). However, a combination of all explanatory variables has a statistically significant effect on the variation in the response variable. All the observed variables show a significant association with the level of use of innovation except market attributes (Table 7).

Technology and market characteristics on level of use of innovations in agribusiness

The model is statistically significant (Table 8). The model stabilized at iteration 4, with the log-likelihood of -3115.0552. Cut 1 up to Cut 5 are just ancillary parameters and thus do not have to be interpreted. The pseudo- R^2 is positive which measures the predictive strength of a model relating the logistic responses to some covariates. Note that the positive pseudo- R^2 observed indicates more significant covariates were included in the model such that if a significant variable is dropped, the pseudo- R^2 tends to reduce. The coefficient values indicate the anticipated fluctuation in the log odds of the dependent variable due to a unit change in the independent parameter. The log odds is the natural log of odds where ‘odds’ is probability(success) / probability (failure).

All factors analyzed in the logistic model except market attributes showed a significant effect on the utilization of innovations with a probability of less than5%. Gender had a positive influence on innovation utilization.

Table 7. The combined effects of relationships of study variables.

Utilization attribute	Coef	Std. Err.	z	P>z	[95% Conf. Interval]	
Gender	0.1486302	0.0556394	2.67	0.008	0.039579	0.2576814
Age	-0.0426956	0.0225025	-1.90	0.058	-0.0867996	0.0014084
Education	0.063293	0.0266745	2.37	0.018	0.011012	0.115574
Commodity	-0.2431445	0.0336455	-7.23	0.000	-0.3090886	-0.1772005
Innovation attribute	-0.2702627	0.0239429	-11.29	0.000	-0.3171898	-0.2233355
Market attribute	0.0028092	0.0262416	0.11	0.915	-0.0486233	0.0542417
_cons	3.371554	0.1526844	22.08	0.000	3.072298	3.67081
Random-effects	**Parameters estimate**				**[95% Conf. Interval]**	
var(Residual)	1.421366	0 .0442559			1.33722	1.510807
Number of obs	2063					
Wald $chi^2(6)$	233.92					
Log likelihood	-3289.9645					
Prob > chi2	0.0000					

Table 8. Ordered logistic regression of technology and market characteristics on utilisation of innovations.

Iteration 0: Log likelihood	-3309.3744
Iteration 1: Log likelihood	-3118.4982
Iteration 2: Log likelihood	-3115.0649
Iteration 3: Log likelihood	-3115.0552
Iteration 4: Log likelihood	-3115.0552
Number of obs.	2061
LR $chi^2(10)$	388.64
Prob > chi^2	0.0000
Log likelihood	3115.0552
Pseudo R^2	0.0587

Utilization attribute	Coef.	Std. err.	Z	P>z	[95% Conf. Interval]	
Gender	0.19	0.08	2.30	0.022	0.03	0.36
Age	-0.06	0.03	-1.66	0.096	-0.12	0.01
Education	0.09	0.04	2.26	0.024	0.01	0.17
Commodity	-0.34	0.05	-6.54	0.000	-0.44	-0.24
Market attribute	-0.04	0.04	-0.97	0.332	-0.12	0.04
Relative Advantage	4.65	1.23	3.78	0.000	2.24	7.06
Compatibility	3.93	1.23	3.20	0.001	1.52	6.34
Trialability	2.50	1.23	2.03	0.043	0.08	4.91
Complexity	-2.52	1.23	2.05	0.040	0.11	4.93
Quality	3.96	1.24	3.18	0.001	1.52	6.39
/cut1	0.59			1.23	-1.83	3.01
/cut2	1.69			1.24	-0.73	4.11
/cut3	3.38			1.24	0.96	5.81
/cut4	5.01			1.24	2.58	7.44
/cut5	6.26			1.24	3.83	8.69

The movement from male to female changes the log odds of level of use of innovation by 0.19 from very low to very high holding other factors constant. The age of participants interviewed in this research has a negative significant effect on the uptake of innovation, implying if other factors are held constant, increasing the number

Table 9. T-test of innovation attribute and market attribute with unequal variances.

Variable	Innovation attribute	Market attribute
Mean	2.415012107	0.880871671
Variance	1.581072977	1.325917844
Observations	2065	2065
Hypothesized mean difference	0	
Df	4096	
t Stat	40.8887011	
P(T≤t) one-tail	0	
t Critical one-tail	1.645225726	
P(T≤t) two-tail	0	
t Critical two-tail	1.960543321	

of years reduces the log odds of utilizing a given innovation by 0.06.

The level of training had a positive significant consequence on the application of technology such that increasing the level of education changes the log odds of innovation application by 0.09. The commodity had a negative consequence on innovation utilization *ceteris paribus*. Moving from commodity 1 (cassava) to commodity 3 (rice) reduced the log odds of innovation utilization by 0.39 from very high to very low.

Apart from complexity which had a negative outcome, the other attributes had a positive consequence on use of the innovation. Other factors constant, an enriched innovation attribute changes the log odds of level of application by the given value with the corresponding level of application. For example, 'relative advantage' increases the log odds of the level of use of attribute by 4.65, 'compatibility' by 3.93, 'trialability' by 2.5, and 'quality' by 3.96 (Table 8).

From the T-test (Table 9), since the P value is 0 (less than 0.05), then it indicates a significant statistical difference between the means of innovation attribute and market attribute. This implies that innovation attributes and market attributes have different effects on the utilization of innovation.

DISCUSSION

Connection between innovation attributes and their use at the farm level

From results of the participants that were interviewed, it was clear that the innovation attributes had a relationship with the level of use of an innovation. The farmers prioritized innovations depending on compatibility, relative advantage, complexity, trialability and quality in that rank. The highlights from the mixed effects model (Table 7) show that all explanatory variables have a significant connection with the level of use of an innovation except market attributes.

Among the 'compatibility' parameters (Table 5), the type of soil and climate were important considerations by farmers that influenced farmer choice on the level of use of innovation. Similarly, varieties that are susceptible to pests and diseases, drought and cannot tolerate marginal soils (risky situations) are associated with low levels of use. These results are in agreement with research findings of a study by Sarel and Marmorstein (2003) which indicated a strong positive connection between understanding how technologies are applied and the perception for the uptake of technology. One of the parameters of 'relative advantage' is initial cost and it directly compares with returns from the innovation (Table 4). From this survey, economic returns of an innovation influenced the level of use of an innovation. Similar observations were made by Mugula and Mishili (2018) who showed that the choice to successfully uptake an innovation was based on economic returns. On the other hand, Liao and Lu (2008) reported that profit margins, low costs of generating products and less labor demanding innovations influenced use of Integrated Pest Management (IPM) practices. Therefore, agribusiness experimenters involved in generating technologies need to consider the factors that are associated with inputs costs and beneficial returns from the innovations.

'Complexity' can be interpreted as difficult to understand or use. The trouble of comprehending a technology can result in low levels of use as shown in Table 6. This could be due to inappropriate use due to inadequate knowledge. This was also reported by Rogers (2003) and Sarel and Marmorstein (2003) who found out that 'complexity' increased the rate of rejection of a technology.

Effect of innovation aspects and demand (market) on the uptake of innovations

Enhancing a given technology attribute increases the log odds of level of application. The variables of complexity reduced the level of use of an innovation significantly (Table 8). Similar results have also been highlighted

(Kolodinsky et al., 2004; Sarel and Marmorstein, 2003; Rogers, 2003). This suggests that in order to increase the uptake of innovations, consideration should be made of what the beneficiary of the technology is looking for in the product that will satisfy his or her needs. It was observed that gender, age and education level of respondents highly influenced uptake of innovations. The influence of gender on the use of the technology is crucial. This is due to the fact that females are involved in production and use of food security crops at subsistence level. The more one grows old the less the energy is available in terms of personal labor to apportion to agriculture. On the other hand, the higher the level of training, the higher the chance of having expertise to apply the innovations. The significant statistical difference between the means of innovation and market attributes (Table 9), implies that innovation attributes and market attributes have different effects on the application of innovation.

CONCLUSION AND RECOMMENDATIONS

The participants prioritized use of technologies based on 'compatibility', 'relative advantage', 'complexity', 'trialability' and 'quality'. There was a strong association between innovation attributes and application of innovations by the farmers from the Kihihi sub-county, Kanugu district. Farmers also considered maize to be more reliable than cassava and rice in the application of innovations. Finally, all other aspects except 'complexity' had a positive influence on the application of technologies. The market aspects did not in any way influence the application of innovations.

The following recommendation are made from the findings above, there is need: (a) To understand end-user needs before starting the process of generating innovations; (b) There is need to find out the challenges within the innovation pathway, and (c) Increase uptake of innovations through incorporating desirable qualities in the innovations.

DECLARATION OF INTEREST

There is no conflict of interest expressed by the authors in this paper.

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