Determinant Factors Affecting the Uptake of Modern Beehives

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Abstract: ***In the recent past, modern technologies in beekeeping have advanced in countries such as China, Argentina, and the USA, which are making honey exports worth millions of dollars. Modern beekeeping in Kenya is still a new idea as in most other African countries. This has led to low benefits from the sector. Despite the efforts made by the government, NGO's and development partners to boost the uptake of modern beehives in Baringo South Sub - County, their level of use remains low. This study seeks to determine the factors leading to low uptake. A multi - stage sampling technique was employed to select the wards and finally, a simple random sampling technique was used to obtain 197 beekeeping agri - entrepreneurs from the Sub - County. Primary data was obtained through interviews using pre - tested semi - structured questionnaires administered by trained enumerators. The data was analyzed and managed using STATA version 15 packages. The findings of the bivariate Probit model revealed that education level, land size, farming experience, household size, distance to the market, gender, extension access, group membership, off - farm income, and credit access have significantly influenced the uptake of modern beehives. These findings will assist policymakers and industries in formulating policies geared towards increased uptake of modern beehives for increased income.***

Keywords: agrienterprise, beehive, beekeeping, bivariate Probit, uptake

1. Introduction

Beekeeping agrienterprise is a common agricultural activity practised in most parts of the world. Bees are economic insects found in most parts of the globe (Chemwok *et al.,* 2016). The origin of seventy percent of the honeyed flora that propagates in the world is Anatolia in Asia (Bunde and Kibet, 2016). Heckle *et al.* (2018), apiculture in general and improved apiculture, in particular, contributes to environmental protection and sustainable agriculture through a reduction of environmental effects from tree felling for traditional beehive construction and from fire hazards from the smoking of hives. Encouragement of apiculture and increases in output of hive products would be following the agricultural sector policies of many African Governments. These often seek to improve household food security concurrently with raising incomes and stabilizing cash flows by improving the productivity of various agricultural and diversified agricultural activities.

Approximately 91 million beehives owned by agri - entrepreneurs are present globally, producing an output of 1.9 million mt of honey, and China leads with an output of 543, 000 metric tons (mt). Other countries include Turkey, Iran, the United States, and Ukraine, with an output of 144, 471 mt, 69, 699 mt, 66, 968 mt and 66, 231 mt, respectively (FAO, 2017). The leading exporters of honey are China 128, 330 mt, Argentina 81, 183 mt and Ukraine 42, 224 mt. Simultaneously, the top importers are the United States of America, Germany and Japan, with imports of 166, 479 mt, 81, 995 mt and 48, 445 mt, respectively (Garcia, 2018).

Kenya ranks third in honey production in the East Africa region, producing 12, 000 mt and 140 mt of beeswax (MOALF, 2019). However, only 20 percent of the country's honey production potential estimated at 100, 000 mt and 60, 000 mt of beeswax has been tapped, and this is particularly so in areas where the agro - ecological and climatic conditions and the land use patterns are near perfect for beekeeping (Chemwok *et al*., 2016). One of the challenges in the enterprise is the method of production.

Modern beekeeping methods emerged wayback in the 18th century in Europe. They started constructing movable comb hives to harvest honey without destroying the entire bee colony. These methods were perfected in Northern America, where the European immigrants continued rearing the European honey bee. In Africa, traditional beekeeping has persisted for a long time and has the longest history; honey hunting and traditional beehives are still common in most African countries (Keiyoro *et al*., 2016).

Like in most parts of Africa, honey production in Kenya comes from traditional hives, which account for 84.6% of the 1.3 million hives in the country. This implies that beekeepers use traditional methods, which presumably lead to low yields and low - quality honey (Muli *et al.*, 2015). According to FAO, between 2015 and 2018, honey production in Kenya declined by 41 percent, from 34, 759 to 20, 525 mt, respectively. These figures indicate poor performance of the sector. The Government of Kenya and non – governmental organizations (NGOs) have supported beekeepers Agri entrepreneurs to improve their beekeeping practices and performance by adopting modern hives like Kenyan top bar hive and Langstroth (Heckle *et al.*, 2018).

Baringo County is one of the major honey - producing areas in Kenya with enormous potential for beekeeping Agri enterprise. However, most of the honey produced comes from the traditional Tugen log hives, which constitute 70 percent of hives in the Sub - County (Chemwok *et al.*, 2016). According to Baringo County livestock statistics (2018), the total number of beehives is 181, 587, with Tugen log hive leading with 84 percent, Kenya top bar hive (KTBH) 14 percent, and Langstroth 2 percent. These traditional log hives are hung on tall trees, making even management practices difficult. The modern beehives are appropriate since they yield 15 - 20 Kg /hive per harvest compared to traditional hives yielding between 5 - 6 Kg/hive (Hailemichael, 2018). The study aims to find out the factors affecting the uptake of modern beehives.

Although various studies have provided evidence on factors influencing the uptake of modern beehives in the world and other parts of Africa, little research work has been done in Kenya. It is thus vital to understand these factors affecting the uptake of modern beehives. Therefore, this study seeks to determine these factors.

2. Literature Review

In the review of the adoption of technologies, Keba (2019) found that participation in community - based groups, farm size, number of beehives the local beekeepers possessed, training, wealth status of beekeepers, non - farm income and age of the beekeeper statistically affected the adoption of improved beekeeping technologies in Ethiopia. By using the double hurdle model, Obuobisa (2017) found that farm size, group membership, off - farm income, own labour, hired labour, non - hired labour and frequency of extension advice significantly affected the adoption of cocoa research innovations in Ghana. It is clear that farmers should be given training through non - formal education and encouraged to join producer associations also extension services should be made available to increase adoption levels.

Cukur and Cukur (2019) used a logistic regression model in determining the factors influencing the implementation of agricultural innovations by beekeepers in Turkey and found that age, access to extension services, membership in a cooperative, and those who have production problems significantly affected the adoption of innovative ways of beekeeping. However, the circumstance of record - keeping, the business manager's circumstance to get a loan, the quantity of honey produced participation in agricultural trade fairs, beekeeping experience, and marketing problems were found to be statistically insignificant.

Albore *et al*. (2019) used the censored Tobit model. They found that total livestock unit perceived cost of technology by farmers, the distance of the market center from home, knowledge about beekeeping management, and the availability of beehive technology were found to significantly influence adoption and intensity of adoption of modern beekeeping technological packages. However, education level of household head, average farm income, training on the management of bees, extension contact, access to credit service, and total household landholding were statistically insignificant in determining adoption and intensity of modern adoption beekeeping technologies in Ethiopia.

Using a multivariate Probit model Belachew *et al*. (2020) found that age, sex, education level, household size, livestock holding, access to credit, size of land, access to extension service and agricultural training were significant in determining the adoption of soil and water conservation practices in Ethiopia. Abadi*et al*. (2018) used and binary logistic regression model and found that family size, sex of the household head, education level of the household head, size of livestock holding, access to extension service, availability of the exotic chicken, distance to the market and training all were significant in determining the adoption of exotic chicken breed production.

Teklewold *et al*. (2013) used multivariate and ordered Probit models to examine rural Ethiopian farmers' adoption of multiple sustainable agricultural practices (SAPs). The analysis revealed that numerous factors influence both the probability and extent of SAP adoption, including credit constraints, a household's trust in government assistance, spouse education, rainfall and plot - level disturbances, household wealth, social capital and networks, labor availability, and plot and market access. Abdul - Hanan *et al*. (2014) also used the Poisson regression model to examine smallholder adoption of soil and water conservation practices in Ghana. Apart from credit, key policy variables such as farm size, group participation, and proximity to input sale points also influenced adoption positively of SWC methods.

3. Methodology

3.1 Study area

The study was done in Baringo County, which is among the 47 Counties in Kenya, situated in the Rift Valley region. Its headquarters and largest town is Kabarnet. The County lies between longitude 35^0 30' and 36^0 30' East and latitude 0^0 10' South and 1^0 40'. It borders Turkana and Samburu Counties to the North, Uasin Gishu to the South West, Laikipia to the East, Nakuru to the South and Elgeyo - Marakwet and West Pokot to the west. The County was chosen because it is one of the counties favourable for honey production in Kenya.

Administratively, the County is divided into 6 Sub - Counties. These are Baringo North, Baringo South, Baringo Central, Tiaty, Mogotio and Eldama Ravine. The County's climate varies from humid highlands to arid lowlands, exhibiting characteristics between these two extremes. The mean annual temperatures range from 21^0C in Southern, South Eastern and South Western parts, while in Central lowlands, the temperatures rise to over 25^0C, with rainfall ranging between 500 to 1000mm (MOALF, 2017).

Baringo South Sub - County was the study area because of its significance in honey production, with an area of 1678Km^2 out of which 215Km^2 constitutes arable land (Baringo County Government, 2018). The area's estimated population is 89, 210; furthermore, the area has four administrative wards: Marigat, Ilchamus, Mochongoi, and Mukutani (KNBS, 2019).

3.2 Sampling procedure

A multi - stage sampling procedure was used to select the 197 respondents for the study. First, Baringo County was purposively chosen because beekeeping is a priority value chain in its annual strategic plan. Baringo South Sub - County was also selected purposively since it is the leading

Sub - County in terms of honey production. Marigat, Ilchamus, Mochongoi, and Mukutani wards in the Sub - County were all selected because they have the highest concentration of beehives. Beekeepers from the four administrative wards were proportionately chosen for the study. Simple random sampling was finally employed to select the respondents based on figures from the Sub - County Agricultural office in Marigat.

3.3 Empirical model

Numerous studies have been conducted on factors affecting the adoption of agricultural technologies, either on the intensity of uptake or identifying the factors associated with the farmers who adopt the technologies. For example, Independent Probit and Logit models have been widely used to analyze factors that influence discrete behaviour, such as adopting decisions (Greene, 1993). However, such specifications would provide inefficient estimates of the parameters of non - adoption models since it ignores the potential correlation between the unobservable captured by the error terms of the two decisions because the non - adoption decision is contingent on the adoption decision. A bivariate Probit can fully address this with a sample selection option (Aklilu and Graaf, 2007). According to Motuma *et al*. (2002), non - uptake is likely to be impacted by the same factors influencing uptake.

Since we only have two beehive options, a multivariate Probit model will not be appropriate since it captures more than two dependent variables that can be estimated simultaneously (Getahun, 2018). A Univariate Probit estimation of choice of each type of beehive used by beekeeper would be misleading for the expected problem of simultaneity. The selection of one type of beehive would be dependent on the selection of the other since beekeepers' choices; decisions are interdependent, suggesting the need to estimate them simultaneously. However, to account for this problem, a bivariate Probit model was employed. A bivariate Probit model, an extension of Univariate binary Probit, is an ideal model since it captures the choice of beehive used by the beekeeper and estimates the correlated binary outcomes jointly against some given explanatory variables in the model. Empirically this model can be presented as follows:

$$Y_{ij}^{*} = \beta_{ij} X_{ij} + \varepsilon_i \qquad \text{Equation 1}$$

With j=1, 2

$Y_i = 1$ if $Y_i^{*} > 0$ and 0 otherwise

Where,

Y_{ij}^{*} is the latent variable, Y_{ij} denoting the probability of choosing j type of the beehive, for i= (Modern beehive) and i= (Traditional beehive) is as follows, thus empirically, the model can be specified as follows:

$$Y_{i1} = \beta_1 X_{iJ1} + \varepsilon_{i1} \qquad \text{Equation 2}$$

$$Y_{i2} = \beta_2 X_{iJ2} + \varepsilon_{i2} \qquad \text{Equation 3}$$

Where, Where, $Y_{i1} = 1$, if beekeeper chooses modern beehive (0 otherwise), $Y_{i2} = 2$ if beekeeper chooses traditional beehive (0 otherwise), X_i = vector of variables factors affecting the choice of beehive, β = vector of unknown parameters (j = 1, 2), and ε = is the error term.

To estimate the above equations, we assumed that the errorterms (ε_1 and ε_2) might be correlated. Then, instead of being independently estimated, they are considered a bivariate limited - dependent - variable model. The two error terms follow a bivariate normal distribution with zero means, variance normalized to unity and a covariance matrix. The covariance matrix is given by:

$$\begin{pmatrix} \varepsilon_{i1} \\ \varepsilon_{i2} \end{pmatrix} \ldots N \begin{pmatrix} 0 \\ 0 \end{pmatrix} \begin{bmatrix} 1 & P_{i12} \\ P_{i21} & 1 \end{bmatrix} \qquad \text{Equation 4}$$

Where P_i represents the correlation between different beehives options ε_{i1} ε_{i2} are the error terms. The off - diagonal components in the covariance matrix represent the unobserved correlation between the stochastic components of different types of beehive options. This assumption means that Equation (4) generates the bivariateprobit model that jointly represents the decision to consider a particular method of the production system. This specification with non - zero off - diagonal elements allows for correlation across error terms of several latent equations, representing unobserved characteristics that affect the choice of the production system (modern beehives and traditional beehives). To conclude the magnitude consequence of the explanatory variables on uptake of the modern and traditional beehive. The respective marginal effects need to be calculated for the variables of interest. Since all the explanatory variables, in this case, are binary, the marginal effects can be inferred as the change (decrease or increase) in the expected value of the dependent variable associated with a change in the respective explanatory variable while other variables remain constant (Gkritza 2009):

$$E[y_1]y_2 = 1, X = 1] - E[y_1[y_2 = 1, X = 0]$$
$$E[y_1]y_2 = 0, X = 1] - E[y_1[y_2 = 0, X = 0] \qquad \text{Equation 5}$$

4. Results and discussion

Descriptive statistics

Results of household characteristics are presented in table 1.

Table 1: Association of household characteristics by farmer type

		Uptake	Non – uptake	Aggregate	
Variable		%	%	%	Chi2
Gender	Male	87.84	46.34	61.93	6.4066***
	Female	12.16	53.66	38.07	
Relationship with the household head	Head	70.27	76.42	74.11	6.7568
	Spouse	25.68	13.82	18.27	
	Child	2.70	8.13	6.09	
	Relative	1.35	0.82	1.02	
Marital status	Married	91.89	78.05	83.25	22.1844**
	Widowed	1.35	4.88	3.55	
	Single	6.76	17.07	13.20	
Source of off - farm	Casual	40.54	34.15	36.55	1.8126
	labour	8.11	13.82	11.68	

income	Civil servant Business	51.35	52.03	51.78	

Note: * and ** = Significant at 1% and 5% respectively**

Many adopter farmers (87.84 percent) were males, while females constituted only 12.16 percent. However, among the non - adopters, males were 46.53 percent, while females constituted 53.66 percent. The chi - square test shows that there was a significant association between gender and the decision to uptake. The results show that many males were adopters of modern beehive compared to the female household counterpart. This is mainly because honey production is the main economic activity for rural households permitted by the existing ecological conditions. This finding corroborates with Jebesa (2017); Bunde and Kibet (2015); Wotro *et al*. (2018), who found gender to be playing a significant role in the adoption of modern beekeeping technologies.

The ownership of modern beehives revealed that 70.27 percent were owned by family heads, 25.68 percent spouses, 2.70 percent children and lastly, 1.35 percent relatives. On the other hand, among non - adopters, 76.42 percent were household heads, 13.82 percent spouses, 8.13 percent children and 0.82 percent relatives. However, the chi - square test statistics indicated no significant association between this variable and uptake of the modern beehive.

The marital status of the household head revealed that for adopters of the modern hives, beekeeper's 91.89 percent were married, 1.35 percent widowed and 6.75 percent single. However, for non - adopters, married beekeepers had a high percentage of 78.05 while widowed and single beekeepers had a percentage of 4.88 and 17.07, respectively. However, the chi - square test indicates a significant association between this variable and the uptake of the modern beehives. The significance of marital status is that married households can make joint decisions derived from different family members' ideas compared to single and divorced households. This result is in line with Wabwile *et al*. (2016), who found that marital status played a significant role in adopting improved sweet potato varieties.

On the source of off - farm income, among the adopters 40.54 percent were casual labourers, 8.11 percent were civil servants and 51.35 percent were doing business. On the other hand, among non - adopters, 34.15 percent were casual labourers, 13.82 percent were civil servants and 52.03 percent were doing business. The chi - square test statistic indicates no significant association among sources of off - farm income and the adoption of modern beehives.

There was a need to establish the differences in household characteristics between adopters and non - adopters of modern beehives and the results are presented in table 2.

Table 2: Mean Difference of Household Characteristics by Farmer type

	Adopters=74		Non - adopters=123		aggregate=197	t - test
Variable	Mean	Std. dev	Mean	Std. dev	Mean	
Age	45.92	12.17	41.92	13.42	43.42	2.1014**
Education	11.59	3.27	5.24	2.55	7.63	15.2011*
Household size	5	2.53	4.93	1.97	4.95	0.2262*
Experience	10.15	6.58	4.04	1.91	6.34	9.6572***
Distance	4.64	3.94	7.3	5.56	6.3	- 3.606
Off - farm income	8370.95	12133.53	12850.41	9927.091	11167.77	- 2.0393
Farming size	4.18	4.1	4.47	3.93	4.36	- 0.4974
Extension	0.5	1.04	1.36	1.85	1.04	- 3.6785
Amount borrowed	7900	25905	13967.48	36000.21	11688.32	- 1.2655
Motivation	3.49	1.42	2.75	1.17	3.03	- 3.9580
Risk	4.11	0.96	2.95	1.17	3.39	- 7.1964

Note: *** and ** = Significant at 1% and 5% level respectively

The mean age differences of household characteristics by beekeeper choice of a beehive are presented in table 4. The aggregated mean was 43.32 years. While the mean age of adopters was 45.92 years with a standard deviation of 12.17 years, on the other hand, the aggregate mean of non - adopters is 41.92 years with a standard deviation of 13.42 years. The t - test result shows a statistical difference in age at a 5 percent significance level. It shows that adopters had statistically higher age than non - adopters did. The age of the adopter plays an imperative role in the uptake of new agricultural technologies. This may be attributed to the ability of older farmers to embrace new technologies compared to the young generations because the young generation does not have enough resources required for uptake of modern technologies. Therefore, it can be concluded that the old age people are the ones doing farming. This result is supported by Abadi*et al. (*2018), who established that the age of the farmer played a significant role in the adoption of the exotic chicken breed production system.

The aggregate mean level of education was 7.43 years of schooling. However, the mean years of schooling for adopters was 11.59 years with a standard deviation of 3.27 years and for non - adopters was 5.24 years of schooling with a standard deviation of 2.55 years. The t - test statistics show a statistical difference on the level of education at a 1 percent significance level. It shows that adopters had more years of schooling than non - adopters, thus able to uptake modern beehives faster than those with fewer years of education. More years of education enables a farmer to understand new technologies faster hence propels uptake. This study tallies with Adila (2017) results who found that education level positively affected the adoption of improved groundnut technology agronomic practices.

The mean difference in household size was 5. However, the mean household size for adopters was 5 persons with a standard deviation of 2.53, while for non - adopters, the mean household size was 5 persons with a standard deviation of 1.97. The t - test results statistics showed no significant difference between adopters and non - adopters with respect to the size of household size. The aggregate years of beekeeping farmers were 6.34 years. Adopter beekeepers had more years of experience at 10.15 years with a standard deviation of 6.58, while the non - adopters beekeepers had an experience of 4.04 years with a standard deviation of 1.91 years. The t - test result statistics show a statistical significance at a 1 percent level. It shows that adopters had more years of experience than non - adopters. Experience gives beekeepers an edge when it comes to adoption since they understand the technologies. This finding corroborates the findings of Tarekegn *et al.* (2018); Awotide *et al.* (2016); Wotro *et al.* (2018); however, on the contrary, Adila (2017) found that farming years of experience was not significant in determining the adoption of agricultural technologies.

The mean difference in distance to the market was 6.3Km. However, the mean distance for adopters was 4.64Km with a standard deviation of 3.94. At the same time, the mean distance for non - adopters was 7.3Km with a standard deviation of 5.56. The t - test result statistics showed no significant difference between adopters and non - adopters in terms of distance they have to reach the market. The aggregate amount of off - farm income was KES 11167.77. However, the mean off - farm income for adopters was KES 8370.95 with a standard deviation of 12133.53. At the same time, the mean off - farm income for non - adopters was KES 12850.41 with a standard deviation of 9927.091. The t - test statistics show no statistical difference between adopters and non - adopters; because those who had off - farm income might not be concerned about modern or traditional beehive as that is not their primary source of income. The results are in line with Adila (2017), contrary to the findings by (Tarekegn *et al*., 2018).

The mean difference in farm size was 4.36 acres. However, the mean size of farm in acres for adopters was 4.18 acres with a 4.1 standard deviation. Then, the mean farm size for non - adopters was 4.47 acres with a 3.93 standard deviation. The t - test result statistic showed that there was no significant difference in land size between adopters and non - adopters. This result is in line with Bunde and Kibet (2016), who found that land size did not play any significant role inthe adoption of modern beekeeping technologies. The aggregate number of extension visits was 1 time. However, the mean average number of visits for adopters was 0.5 with a standard deviation of 1.04, while for non - adopters, the average number of visits was 1.36 with a standard deviation of 1.85.

The mean difference in motivation status was 3.03. However, adopters' mean scale of motivation status was 3.49 with a 1.42 standard deviation, while the mean scale of motivation for non - adopters was 2.75 with a 1.17 standard deviation. The t - test statistics showed that there was no significant difference in motivation status between adopters and non - adopters. The mean difference in risk status was 3.39. However, adopters' mean scale of risk status was 4.11 with a 0.96 standard deviation, while the mean scale of motivation for non - adopters was 2.95 with a 1.17 standard deviation. The t - test statistics showed that there was no significant difference in motivation status between adopters and non - adopters.

There was need also to understand the institutional characteristics of adopters and non - adopters and the results are presented in table 3.

Table 3: Institutional characteristic results of adopters and non - adopters

Variable		adopters=74	non - adopters=123	Chi2
Group membership	Yes No	70 (94.59) 4 (5.41)	38 (30.89) 85 (69.11)	75.6958***
Extension Access	Yes No	60 (81.08) 14 (18.92)	41 (33.33) 82 (66.67)	42.1615***
Credit access	Yes No	67 (90.54) 7 (9.46)	43 (34.96) 80 (65.04)	57.8824***
Nature of the road	Murrum Tarmac	41 (55.41) 33 (44.59)	113 (91.87) 10 (8.13)	36.0043***

Note * = significant at 1% level**

The majority of the adopters at 94.59 per cent were members of a group and only 5.41 percent of adopters were not members of a group. Among non - adopters, 30.89 percent were members of a group, whereas 69.11 were non - members. The chi - square test statistic showed that there was a positive significance of 1 percent level between group membership and the decision to uptake modern beehive, the result merges the findings of Oluwatusin and Adesakin, (2017) who found that group membership played a significant role in the adoption of improved agricultural technologies among cassava farmers. On extension access 81.08 percent of adopters accessed extension services while 18.92 percent did not. On the other hand, 33.33 percent of non - adopters accessed extension while 66.67 percent of non - adopters did not access extension service. Access to extension service positively and significantly influenced modern bee hives' uptake at a 1 percent level. This finding corroborates Gao *et al.* (2020) findings, who concluded that access to extension services was essential in facilitating the adoption of agricultural technologies among maize farmers.

A large number of adopters at 90.54 percent had access to credit, whereas only 9.46 percent did not access it. Among non - adopters, only 34.96 percent accessed credit while 65.04 percent did not access credit. The chi - square test statistic showed that credit access positively and significantly influenced modern beehives' uptake at a 1 percent significant level. This result is in line with Udimal*et al.* (2017 who concluded that credit access played a vital role in adopting agricultural technologies in improved rice varieties. Credit access allows beekeepers to purchase modern beehives that are expensive compared to the traditional ones. Among adopters, 55.51 percent got accessed to murram roads while 33 percent used tarmacked roads.

Conversely, 91.87 percent of non - adopters got access to murram roads, while 8.13 percent got access to tarmacked roads when going to the market. This justifies that most of the roads in the area are in poor condition, making it difficult for them to access the input and output market. The chi - square test statistic showed that the nature of the road was significant at a 1 percent level in determining the adoption of modern beehives.

Econometric analysis

This section presents the diagnostic test for the variables used in the econometric analysis to determine Multicollinearity and heteroscedasticity.

Preliminary data analysis

A multicollinearity test was done using variance inflation factor (VIF) for all the continuous variables as shown intable 3 below and pairwise correlation for all the categorical variables as in table 3 below, before econometric analyses. Multicollinearity is a statistical phenomenon where there is a perfect relationship between forecast variables (Yang and Wu 2016). When some of the predictor variables are correlated with other predictors, it may lack statistical significance for the individual predictor variable even though the model may be significant. The recommended variance inflation factor should be below the standard cutoff threshold of ten or a more restrictive criterion because VIF should be less than five (Hair *et al.*, 2011; Deoud, 2017; Salmeron *et al.*, 2018; Thomson *et al.*, 2017). A variance inflation factor measures how much the variance of projected coefficients is exaggerated compared to having uncorrelated coefficients. The VIF was specified as follows:

$$\text{VIF}\ (x_i) = \frac{1}{1-R_i^2}$$

Where:

VIF (x_i) – Variance inflation factor for the explanatory variable $x_i$correlation

R_i^2 - Squire of multiple correlation coefficient obtained from regressing x_i on the remaining explanatory variables

The variance inflation factor for the variables was below the required threshold of 10 and less than the restrictive value of 5 as presented in table 4, meaning that there is no serious problem with Multicollinearity. Variance inflation factor that exceeds 5 or 10 implies that the associated regression coefficients have been estimated poorly because of Multicollinearity.

Table 4: Results of explanatory variables using variance inflation factor (VIF)

Variable	VIF	1/VIF
Education level	1.87	0.535954
Farming experience	1.56	0.639101
Entrepreneurial risk	1.53	0.65433
Group membership	1.52	0.658468
Extension access	1.3	0.76644
Motivation	1.28	0.781247
Gender	1.23	0.812263
Household size	1.22	0.822266
Land size	1.18	0.845704
Off - farm income	1.17	0.851918
Distance	1.16	0.863713
Credit	1.07	0.938102
Mean VIF	1.34	

The pairwise correlation values for the model variables ranged between 0.0059 to 0.3452, which was below the accepted cutoff point of 0.5 as presented in table 5. This indicated that there was no association or relationship among the categorical variables used in the study.

Table 5: Pairwise correlation test for categorical variables

	Gender	Extension access	Group membership	Off - farm income	Motivation	Entrepreneurial risk
Gender	1					
Extension access	0.0722	1				
Group membership	0.2335	0.2781	1			
Off - farm income	- 0.0059	0.0931	0.0391	1		
Motivation	0.1746	0.2202	0.1498	0.2738	1	
Entrepreneurial risk	0.3157	0.1664	0.328	0.2577	0.3452	1

Heteroscedasticity was tested using the white test and the results are as shown in table 6. Heteroscedasticity is one of the violations of the linear regression model where the variances across observation are not constant (Greene, 2012). Breusch Pagan test is only designed to test linear form of Heteroscedasticity vis a vis white test allows the independent variable to have a nonlinear and interactive effect on the error variance. The white test is more powerful than Breusch Pagan since it can detect a more general form of heteroscedasticity (Woolridge, 2004). The results showed no major problem of heteroscedasticity as the probability chi - square was 0.3881which is greater than 0.05; therefore, we fail to reject the null hypothesis.

Table 6: Heteroscedasticity test

Source	chi2	Df	P
Heteroscedasticity	89.1	86	0.3881
Skewness	23.85	12	0.0213
Kurtosis	0.16	1	0.6865
Total	113.12	99	0.1572
chi2 (86) = 89.10			
Prob > chi2 = 0.3881			

chi2=chi - squire; df=degrees of freedom and p - value=significance level

Empirical results

For this objective bivariate probit model was used to analyze factors affecting the uptake of modern beehives. Table 7 below shows the results of the bivariate probit model. The dependent variables are modern beehive and traditional beehive. Tests for the goodness of fit indicated that data fits the model reasonably well. The Wald test that all the coefficients are jointly equal to zero is rejected (Wald chi2 (26) =64.25; Prob=0.0000. Meaning all the independent variables are statistically significant. The likelihood test ratio (LR test Chi (2) =14.5181 Prob>chi2=0.000) compares this model with other alternative models. The likelihood test ratio (LR test was significant at a 1 percent level, meaning the data fits the bivariate Probit model well.

Table 7: Results of the bivariate Probit model for the factors affecting uptake of modern beehives

	Modern beehive		Traditional beehive	
Variable	Coeff	std. Err.	Coeff	std. Err
Age	- 0.017	0.019	0.020	0.018
education level	0.239***	0.067	- 0.162*	0.083
Land size	0.101	0.067	0.336*	0.114
Farming experience	0.230**	0.082	- 0.122**	0.049
Household size	- 0.257*	0.114	0.029	0.080
Distance	- 0.042	0.043	0.156**	0.066
Gender	1.764***	0.640	- 0.895	0.719
Extension access	1.096**	0.453	- 0.610	0.450
Group membership	1.509**	0.544	1.156	0.869
Motivation	0.044	0.165	- 0.079	0.179
Entrepreneurial risk	0.248	0.221	- 0.611**	0.264
Off - farm income	- 0.885**	0.425	0.135	0.508
Credit access	0.000***	0.000	0.000***	0.000
_cons	- 5.017	1.321	4.236	1.405
Number of observations=197 Wald chi2 (26) =64.25 prob>chi2=0.0000 LR test RHO=0: chi2 (1) =14.5181 prob>chi2=0.0001				

*, **, *** denotes statistical significant at 10%, 5% and 1% level respectively

The maximum level of education of the household head had a positive and a negative effect on uptake of modern and traditional beehive respectively. The odds favouring the adoption of modern beehive increased by 0.239 for beekeeper farmers who had additional years of education, while the odds reduced by 0.162 for the traditional beehive. The results are in favour of prior expectations. The implication of this is those farm households with more years of schooling are most likely to uptake modern and more sophisticated technologies than those without. This is because educated households bring home new modern agricultural technologies, especially improved crop varieties and livestock breeds for family members to adopt. Further, education enables farmers ability to obtain processes and be more rational and able to analyze the benefits of the new technology. The finding asserts Bunde and Kibet (2015); Affognon *et al*. (2015) found that education positively affected the adoption of modern beekeeping technology.

Land size owned by the household head had a positive effect on the use of traditional beehives and was significant at a 10 percent level. This was contrary to the hypothesized result. The odds favouring traditional beehive increased by 0.336 for every increase of land size per acre. The likely reason for this is that farmers who had large tracks of land hanged their traditional beehives in acacia trees within their land since there was no much monitoring required compared to modern beehives. This result is contrary toGebiso (2015) findingsthat the increase in land size had a positive effect and was significant in adopting modern beehives. However, Bunde and Kibet (2015) found this variable insignificant in determining the adoption of modern beehive technologies. Ntshangase *et al*. (2018) also found that land size was not significant in determining the adoption of no - till cultivation agriculture.

The farming experience of the beekeeper had a positive and a negative effect on the uptake of modern and traditional beehives respectively. The odds favouring modern beehive increased by 0.230 for every increase in farming experience by one year. The odds for traditional decreased by 0.122 for every increase of experience by one year. The positive effect on the uptake of modern beehive might be attributed to the fact that experienced farmers might want to try new modes of production compared to beekeepers withfewer years of experience. The negative effect on the use of traditional beehives probably might be explained by the fact that beekeepers want to increase their production and probably are demotivated by the low productivity from the traditional beehives. Longer farming experience implies accumulated farming knowledge and skill, which contributes to the adoption of the modern beehive (Ainembabazi 2014 *et al*.; Wongelu, 2014; Bekuma, 2018). On the contrary, Mujuni *et al*. (2012) found that the beekeeping year of experience was not significant in determining the adoption of the modern beehive and associated technologies.

Household size had a negative effect and was significant at a 10 percent level in determining uptake of the modern beehive. The odds in favour of uptake decreased by 0.257 for every increase in one household member. The result is contrary to the hypothesized result that large family size will positively affect the uptake of the modern beehive. The possible explanation for the negative effect is that a large family will require more money to meet household needs like food, shelter, and medication, leaving little money for farming and uptake of the improved beehives. The result is also supported by earlier studies (Adgaba 2014; Bekuma 2018). On the contrary, Onyeneke (2017) found that large household size influenced the adoption of improved technologies in rice production because the new technology requires additional labour from the family.

Distance to the nearest market positively affected beekeepers using traditional beehives and was significant at a 5 percent level. The result goes against the priori that an increase in distance will have a negative effect on the adoption of modern beehives. The odds in favour of traditional beehive increased by 0.156 for every 1Km increase to market. The possible explanation for this is that farmers might be spending a lot of money on transporting honey to the market hence remaining with a little amount to change the type of beehive they are using. However, the result is inconsistent with Tedele (2016) findings, as distance to the market was significant and had a positive effect on the adoption of modern beehives.

Gender of the household head had a positive impact on the uptake of modern beehives and was significant at a 5 percent level. The odds in favour of uptake increased by 1.764 if the beekeeper is male. The result is in line as hypothesized in the research. The possible explanation for this is that men are in control and access to resources required to facilitate the adoption of modern technologies. Therefore, being male increases the probability of adopting the modern beehive compared to females who have less control over agricultural resources. Besides, male households have more access to information on new technologies compared to females. The results are in line with Teshome *et al*. (2019) found that age is positively significant in determining the adoption of improved Jalanea potato variety.

Extension access had a positive effect and was significant at 5 percent in determining uptake of modern beehives. The odds favouring uptake of modern beehive increased by 1.096 for beekeeper farmers who have extension contact access. Education increases the beekeepers' knowledge of modern beehives as they get more access to vital information. It also provides a platform for an in - depth understanding of the technology, which helps apply the technology. Extension agents popularize innovation and new technology by making farmers exchange ideas and experience as cheaper sources to acquire information; extension officers establish demonstration points where farmers get hands - on learning and experiment with new farming techniques. Therefore, as hypothesized farmers who had regular visits to extension offices and those who participated in agricultural field days were more likely to adopt the modern beehives. This result corroborates with Jebesa (2017) findings, who found that extension service played a vital role in determining the adoption of modern beehives.

Group membership had a positive effect and was significant at a 5 percent level in determining uptake of modern beehives. The results indicate being a member of a group increases the uptake of modern beehives with odds of 1.509. The positive effect might likely be due to an increase in meeting with other new farmers as one becomes informed on new upcoming agricultural technologies and gives them a chance to exchange knowledge and expertise with other beekeepers in the group. This motivates them to adopt modern beehive technology. The present findings concur with previous results (Tamrat, 2015; Tarekegn *et al*., 2018; Albore *et al*., 2019)

Participation in off - farm activities other than beekeeping negatively affected the probability of uptake at a 5 percent level. The discovery shows that having an increase of off - farm income by 1 KES decreases uptake by odds of 0.885. The possible justification for this is that beekeepers who had off - farm income might have diverted the money to other uses. This result is contrary to the earlier hypothesis in the study. This result conforms to Fikadu (2017) study who found that off - farm income had a negative effect on the adoption intensity of modern beehives. On the contrary, Kiingwa *et al*. (2020) found that off - farm income positively affectedthe adoption of modern beehives.

Access to credit to purchase modern agricultural technologies is another factor found to be significant at 1 percent level for modern users and 1per level for traditional users. The positive effect on modern users is in line with the earlier expectation that access to credit will influence uptake. A possible reason behind this is that those farmers who had access to credit sources will purchase modern beehives and reap the related benefits than those without access to credit since most modern technologies are expensive for many small - scale farmers, especially those in rural areas where poverty is pervasive. The positive value on the use of traditional beehive might be because farmers who acquired credit might have diverted the money into other uses like paying hospital bills, school fees, or even buying meals for their families. The results are consistent with the findings that credit access plays a significant role in the adoption of modern beehives (Yeheula *et al*., 2016) in the other hand Abdallah (2016); Bortamuly and Goswami (2015): Mwangi and Kariuki (2015) found that credit access played an important role in technology adoption. Also, Bircan *et al*. (2015) noted that access to bank credit facilitated technological diffusion and new production methods.

5. Conclusion and Recommendation

5.1 Conclusion

The study aimed at identifying the factors influencing the uptake of modern beehives. Findings from the study revealed that socio - economic factors, institutional factors, entrepreneurial factors, and beehive attributes are very important in determining the uptake of modern beehives. The bivariate probit models results show that: education level of the farmer, farming experience, gender, extension access, land size, group membership, distance, off - farm income and access to credit influenced the choice of the beehive the farmer was using. Further, the bivariate probit model results exposed that age and motivation played no significant role in determining the uptake of modern beehives.

5.2 Recommendation

Based on the deductions, the following recommendations are drawn for increased adoption of modern beehives:

Training of beekeepers should be given priority by the government and other stakeholders dealing with beekeeping. This training should focus onadopting modern beehives and the appropriate use of chemicals, particularly pesticides, to minimize the deaths of honeybees.

Extension services should be provided to all farmers, especially those in villages lacking adequate information about modern beekeeping.

Credit facilities should be extended to farmers, especially those in rural areas, to minimize financial constraints. Beekeepers can use the loan to purchase modern beehives and also to purchase other modern beekeeping equipment.

Group formation should be encouraged since it facilitates the uptake of modern beehives as farmers learn from each other. Also, it is easy for the extension officers to train farmers in groups than those not in groups.

6. Further Research

The study was carried out in Baringo South sub - county. The researcher suggests further research in the following areas:

1) Factors influencing high absconding of bees from modern beehives.
2) Impact use of modern beehives on the livelihood of beekeepers
3) Similar studies do be done in different sub - counties in Baringo to establish the factors influencing the adoption of modern beehives and comparison purposes.

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