Adoption and Intensity of Use of Modern Beehives in Wag Himra and North Wollo Zones, Amhara Region, Ethiopia

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Abstract

The objectives of the study were: (1) to quantify the determinant factors of adoption probability, (2) to evaluate the intensity of modern beehive use, and (3) to identify the major constraints of honey production using modern beehives in Wag Himra and North Wollo zones, Amhara region, Ethiopia. Multi-stage sampling methods were employed. 268 rural beekeepers taken from adopters and non-adopters were interviewed this study using the proportional random sampling method. Among the 268 bee-keepers, 97 (36.19%) were adopters while 171 (63.81%) were non-adopters. Descriptive analysis and the econometric (double-hurdle) model were applied using SPSS-22 and STATA-12, respectively. The first hurdle result revealed that age, number of livestock owned, educational level, number of local hives beekeepers possessed, training provided, total annual income of bee-keepers, credit service, distance to Woreda agricultural office, extension service, and participation on off-farm activities were the main factors that affected the probability of adoption decision. The second hurdle revealed that age, number of local hives bee-keepers possessed, training provided, credit service, and distance to Woreda agricultural office were the main factors that affected the intensive use of modern beehives. Additionally, pests and predators, drought, and lack of bee equipment and accessories ranked first, second and third major constraints of bee-keeping, respectively, which led to bee colonies absconding and honey yield declining. Based on the findings, the authors recommend that the major factors in adoption decision and intensive use of modern beehives should be considered by policymakers and planners in setting their policies and strategies of honey production improvement interventions.

Keywords: apiculture, adoption, modern beehive, double-hurdle model, intensity
JEL Classification: O12, O13, Q16

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1. Introduction

Bee-keeping in Ethiopia is common and one of the agricultural activities. Honey and beewax are the major bee products used for export earnings and also serve as sources of income for the rural community. Ethiopia is the leading honey producer in Africa and is one of the ten largest producers in the world (with around 23.6% of the African and 2.1% of the world production) (Kassaye, 1990).

Honey is used for the preparation of a traditional alcoholic beverage (*Tej*) and traditional medicine, whereas bee wax is used for the preparation of a traditional candle (*Tuaf*), which is used for religious purposes in the local area. In addition, bees play a part in the pollination of fruits, vegetables, and cereal crops, thereby contributing to an improved production and productivity of food crops.

In recent years, the Ethiopian government, under its agricultural-led development policy, has given due attention to apiculture. Apicultural development is one of the development strategies of the Amhara region and areas have been categorized based on prioritized potentials. For instance, the Wag-Lasta area development strategy focuses on the development of small ruminants and apiculture. To this effect, different private and public institutions such as the Amhara Agricultural Research Institute, the Small and Medium Enterprises, the Amhara Region Agriculture Bureau, and other non-governmental organizations have been involved in technology generation and adaptation, modern beehive box production, and dissemination. Moreover, public and private companies such as Lalibela Honey and Bee Wax Museum and TIRET (a private company) Honey and Bee Wax Factory are being established.

To increase production and productivity of honey and bee wax, different improved technologies have been used in the last 7-10 years. Some of the technologies are a transitional beehive, a modern beehive, a honey presser, a water sprayer, a smoker, gloves, a honey extractor and a veil. A modern bee box-hive has been disseminated to the farmers through the offices of agriculture and different governmental and non-governmental organizations to improve the production potential of bees by creating a favorable working and living environment.

The modern beehive box has a production potential of 20-30kg per colony per year of honey while the traditional beehive produces 5-10kg per colony of honey (Holeta Bee Research Center, 2004). Due to institutional, socio-economic, biophysical and other implicit and explicit factors, the adoption and intensive use of modern beehives by the farmers is not described well through different organizations are struggling to disseminate modern beehives to farmers. That means very little information has been generated on socio-economic, institutional and biophysical determinants of adoption of improved beehives in the Amhara Region so far. Therefore, this study attempts to generate such information that could help to develop policies and strategies in line with the unique characteristics of the study area.

Objectives

General objective:

- The general objective of the study is to assess the adoption and intensive use of the modern beehive with its determinant factors.

The specific objectives are:

- to analyze the factors affecting the adoption of the modern beehive;
- to evaluate the extent and intensity of adoption of modern beehives; and
- to identify the constraints of modern beehive adoption.

2. Literature Review

Adoption was defined by Feder, *et al.* (1985) as the degree of use of new innovation by a farmer when he has got full information about the new innovation and its potentials. The author classified adoption of new technology into two as 'individual' and 'aggregate' adoption. Accordingly, they defined individual adoption as the farmer's decisions to incorporate a new technology into the production process and aggregate adoption as the process of diffusion of a new technology within a region or population. Furthermore, Rogers and Shoemaker (1971) defined technology adoption as the decision made by a farmer to use a new technology as the best course of action he ever practiced. Adoption of new technology in agriculture, which occurs due to behavioral changes like desirable changes in knowledge, understanding, and ability to apply technological information; changes in feeling or behavior such as changes in interest, attitudes, aspirations, values and the like; and changes in overt abilities and skills, is determined by many socio-economic factors (Ray, 2001; Salim, 1986).

Adoption is not a simple, overnight activity, but it is a mental process which an individual farmer (decision-maker or a group of a decision maker's family members) goes through for decision-making. To ensure the adoption of a new innovation, the fulfillment of specific economic, technical, and institutional conditions are required. From the farmers' perspective, the new technology should be economically more profitable than the existing alternatives. Moreover, the new technology should be technically easy to manage by smallholders and adapt to the surrounding socio-cultural situations. Also, the availability of the new technology and all its necessary inputs to smallholders at the right time and place and in the right quantity and quality is a necessary condition (Ehui *et al*., 2004). In general, adoption is a function of five characteristics of the technology. These are relative advantage or profitability, compatibility or riskiness, complexity, triability/divisibility or initial capital requirements, and observability or availability (Rogers, 1971). A study by Tamrat (2015) shows that the main determinants of modern beehive adoption in Arsi zone, Ethiopia, were farmyard size, a number of local beehives bee-keepers possessed, training provided, participation on demonstration, wealth status of bee-keepers, and participation of bee-keepers on non-farm income sources. Moreover, chemical application, bee predators, lack of knowledge and skill on modern beehives, lack of modern beehive accessories, lack of bee forage, and lack of capital were the major bee-keeping bottlenecks.

Workineh (2007) found that credit, knowledge on practical activities of the technology, education level of household head, positive perception of modern beehive technologies, and apiary demonstration visit were most determinant factors of adoption of improved beehives. The study done on adoption and profitability of a Kenyan transitional beehive, which may be the first adoption study in Ethiopia also evidenced that household farm experience, perception of timely supply of the technology, extension contact, and visit to apiaries are major adoption determinants (Melaku (2005), as cited in Tamrat (2015)). Cramb (2003) inferred that different demographic and socioeconomic characteristics of farm-household are associated with technology adoptions such as age, education, and personal characteristics of the household head; size, location, and tenure status of the farm; and availability of cash or credit for farm investment and access to markets for farm produce. Feder *et al.* (1985) in their research report stated that credit, farm size, risk, labor availability, and human capital, land tenure and education are main factors affecting technological adoption.

3. Research Methodology

3.1 Description of the study area

The study was conducted at Wag Himra and north Wollo zones of the Amhara National Regional State, particularly in Sekota (Aybra and Woleh), Gazgibla (Zarota and Asketama 01), and Ziquala (Ziquala 01 and Ziquala 02) districts of Wag Himra zone and Lasta (Yimraha, Blbala and Debre Loza) and Bugna (Kidus Harbie, Laydba and Birko) districts of north Wollo (found inside the Tekezie basin growth corridor) of Amhara region in the 2015 production year (Figure 1).

3.2 Sampling techniques

Multi-stage sampling techniques were employed. In the first stage, five districts were selected purposively based on bee-keeping potential and modern beehive technology promotion through secondary data from zonal agriculture offices. Accordingly, Sekota, Gazgibla and Ziquala districts from Wag Himra, and Lasta and Bugna districts from North Wollo zones were selected. Then, in the second stage twelve Kebele’s in which the modern beehive was promoted were selected purposively. Accordingly, Woleh, Aybra, Asketama 01, Zarota, Ziquala 01, and Ziquala 02 Kebele’s from Wag Himra zone, and Debre Loza, Yimraha, Blbala, Kidus Harbie, Laydba and Birko Kebele’s from north Wollo were selected. In the final stage, 268 respondents were selected for formal interview using proportional random sampling techniques from adopters and non-adopters in the sample Kebele’s.

3.3 Method of data collection

Primary and secondary data were collected. Primary data were collected from district agriculture experts, Kebele DA's, and model farmers through key informant interviews. A preliminary survey was conducted to assess the potentials of each district in bee-keeping and the potential challenges of bee-keeping in the study area in order to better inform the questionnaires. In the second stage, structured questionnaires were prepared for formal interviews. Secondary data were collected from working documents of zonal, district, and Kebele agricultural offices.

3.4 Method of data analysis

The data were analyzed with descriptive statistics and econometric models. The descriptive statistics were percentages, means, and standard deviations whereas for inferential statistics t-test, x^2-square were used for continuous and categorical data, respectively, with SPSS V-22. Moreover, double hurdle model with STATA were employed to analyze the determinants and intensity of adoption of the modern beehive.

3.5 Analytical Model

Specification of econometric models

In principle, the decisions of whether to adopt and how much to adopt can be made jointly or separately. It can be argued that adoption and intensity of use decisions are not necessarily made jointly (Berhanu and Swinton, 2003). The Tobit model was used for the analysis under the assumption that the two decisions are affected by the same set of factors (Green, 1993). On the other hand, in the double hurdle model, both hurdles have equations associated with them, incorporating the effects of farmers' characteristics and circumstances. Such explanatory variables may appear in both equations or in either of them. Most prominently, a variable appearing in both equations may have opposite effects in the two equations. The double hurdle model (Cragg, 1971) has been extensively applied in several studies such as Burton *et al*. (1996), Newman *et al*. (2001), and Mofatt (2003). Hailemariam *et al.* (2006) was among those who employed double hurdle in studying the adoption of improved poultry breeds in Ethiopia. The double hurdle model is a parametric generalization of the Tobit model in which two separate stochastic processes determine the decision to adopt and the level of adoption of technology. The double hurdle model has an adoption (D_i) equation:

$$D_i = Z_i'\boldsymbol{\alpha} + u_i \qquad \textbf{(1)}$$

$$D_i^* = Z_i'\alpha + u_i \quad \text{Where} \quad D_i = \begin{cases} 1 & \text{if } D_i^* > 0 \\ 0 & \text{otherwise} \end{cases}$$

Where Di is a dummy variable that takes the value 1 if the farmer adopts the modern beehive and zero otherwise; Z is a vector of household characteristics and α is a vector of parameters.

The level of adoption (Y) has the following equation:

Yi* = ßXi + Vi

Yi = Yi* if Yi* >0 and Di>0

Yi = 0, otherwise **(2)**

Where, Yi is the observed variable representing the proportion of the modern beehive (frame hive); X is a vector of the individual's characteristics and ß is a vector of parameters.

$$\text{Yi} = \frac{\text{number of modern (frame) hive owned}}{\text{totla number of beehive (frame+traditional+trnsitional)owned}}$$

The error terms Ui and Vi are distributed as follows:

$$\left\{ \begin{array}{l} \text{Ui} \sim \text{N}(0,1) \\ \text{Vi} \sim \text{N}(0,\sigma^2) \end{array} \right\} \qquad \textbf{(3)}$$

Finally, the observed variable Yi in the double hurdle model is determined by

Yi = Di Yi* **(4)**

The log-likelihood for the double hurdle model is:

$$Log\ L = \sum_{0}\left[1-\Phi\left(Z_i'\boldsymbol{\alpha}\right)\right] + \sum_{+}\left[\Phi\left(Z_i'D_i\right)\frac{1}{\sigma}\varphi\left(\frac{Y_i - X_i'\boldsymbol{\beta}}{\sigma}\right)\right] \quad \textbf{(5)}$$

Where, 0 indicates summation over the zero observations in the sample, while + indicates summation over positive observations, and Φ (.) and ϕ (.) are the standard normal cumulative distribution functions and probability distribution functions, respectively. Under the assumption of independence between the error terms Vi and Ui, the model as originally proposed by Cregg (1971) is equivalent to a combination of a truncated regression model and a univariate Probit model. The Tobit model, as presented above, arises if

$\lambda = \frac{ß}{\sigma}$, and X = Z

A simple test for the double hurdle model against the Tobit model can be used. Therefore, one simply has to estimate the truncated regression model, the Tobit model, and the Tobit model separately and use a likelihood ratio (LR) test. The LR statistics can be computed using Green (2000):

$$\Gamma = -2[\ln L_T - (\ln L_P + \ln L_{TR})] \sim \chi^2_K \quad \textbf{(6)}$$

where, L_T is the likelihood for the Tobit model; L_P is the likelihood for the Probit model; L_{TR} is the likelihood for the truncated regression model and K is the number of independent variables in the equations. If the test hypothesis is written as:

H_0: $\lambda = \frac{\beta}{\sigma}$, and $\lambda \neq \frac{\beta}{\sigma}$ H_0 will be rejected on a pre-specified significance level if $\Gamma > \chi^2_K$

Note: The hypotheses and definition of all working variables were depicted in Table 1 in the Annex.

4. Results and Discussion

4.1 Demographic and socio-economic characteristics of the respondents

As depicted in Table 2, among the total number of respondents, 95.5% are male-headed and 4.5% are female-headed households. Among the total sample of households, 2.9% of the female-headed and 60.8% of the male-headed households were adopters but the chi-square value is insignificant. The result of the chi-square test ($\chi 2$-test) showed a significant and positive association between level of education and adoption of modern beehive, which is significant at less than 1% level of significance. As the chi-square test ($\chi 2$ -test) shows, access to extension service and provision of training on modern bee beehive technology; involvement in off-farm activities; access to credit service; and involvement in formal institutions have a positive and significant association on the probability of adoption of the modern beehive at less than 1%, at 1%, 2%, and at less than 5% level of significance, respectively.

The survey results presented in Table 3 reveals that the households' average age was 48 years while the mean ages for adopters and non-adopters were 46.86 and 50.02, respectively, with a significant mean difference at 10% level. The households' average tropical livestock unit was 5.125 TLU, with 5.697 TLU and 4.1168 TLU for adopters and non-adopters, respectively, and the mean difference was significant at 5% level. The T-test also shows that the average total income of farm households was 29320.4179 *birr* .The mean total annual incomes for adopters and non-adopters is 32977.43 *birr* and 22873.52 *birr,* respectively, and the mean difference between adopters and non-adopters was significant at less than 1% level.

Honey yield

The survey results depicted in Table 4 shows that the honey yield of frame hive was by far better than that of the traditional beehives in the areas. The minimum and maximum yield value of the frame hive was 8.5kg and 26kg per hive. Therefore, the average honey yield per hive from frame hive in the 2006 and 2007 production years was 14.3kg and 13.5kg, respectively. On the contrary, the average honey yield per hive from traditional hives in the 2006 and 2007 production year was 4.9kg and 4.4kg, respectively. Thus, the use of frame hives had a yield advantage of 9.1kg or 67.41% compared with the yield from traditional beehives. In line with this, the result of Adebabay *et al.* (2006) showed that the average quantity of honey per hive harvested in similar areas from traditional, transitional, and frame beehives was 9.87kg, 12.75kg, and 11.62kg, respectively.

Major constraints of bee-keeping in the study area

As depicted in Table 5, 44% of the respondents ranked pests and predators as the first and major constraints of bee-keeping; 20.5% of the respondents ranked drought as the second major constraint of beekeeping which results in shortage of bee forages and causes bee colonies to abscond; 13.4% of the respondents ranked lack of bee-keeping equipment (like modern beehives, wax molds, honey extractors, queen excluders) and accessories (like smokers, cloths, bee veils, brushes) as the third major constraint of the bee-keeping sector which hinders the farm households from implementing appropriate improved beehive management practices (like internal inspection of hives, adding and reducing supper) on time. The fourth, fifth, sixth and seventh major constraints were the application of herbicides on crops, bee-keeping skill, shortage of bee forage, and financial constraints, respectively.

As shown in Table 6, among different pests and predators which highly affect bee colonies, 32.1% of the farm households ranked ants as the most common pests while 30.6% and 29.5% of the respondents ranked wax moth and birds as the second and the third common pests and predators, respectively. And the remaining 5.2%, 1.5%, and 1.1% of the respondents ranked spider, lizard, and honey badger as fourth, fifth, and sixth common pests and predators, respectively, in the study area.

Current status of modern beehive adoption

According to the survey results shown in Table 7, out of 268 respondents, only 171(63.81%) are adopters of modern beehives and the remaining 97(36.19%) are non-adopters. Among all adopters, 35(20.5%) discontinued the use of modern beehive production due to Tough hive management, pest occurrence (typically wax moth), Lack of inputs (wax, reconstructing material, smoker), Lack of skills (wax casting, honey harvesting, honey extracting), Pest occurrence and lack of inputs, absconding, drought.

Colony management practices

According to the survey results, external inspection is more common than internal inspection except when it is honey harvesting time. The sample respondents indicated that they remove all combs from traditional hives and they find it difficult to change the old combs for modern hives due to shortage of wax, the cost of wax, and lack of awareness. 33.2% of the entire respondents changed the old comb of the colony, while the remaining 66.8% did not do so. The result of (χ2-test) showed a significant and positive association between the comb change practice and the probability of making a decision to adopt modern beehives, which is significant at less than 1% level of significance. This indicates that the bee-keepers that change the old combs have better bee-keeping practice than the bee-keepers that did not change the old comb.

Supplementary feeding practices

Regarding supplementary feeding, almost all non-adopters and adopters did not give supplementary feed to the colony when there was shortage. However, 60(22.4%) adopters gave supplementary feeding like malt powder, sugar, *shiro* and honey and also water when there was shortage throughout the year. As shown in Figure 2, there is a positive association between supplementary feeding and adoption of modern beehives. Thus, it makes the colony active and prevents it from being attacked by different pests and predators easily. According to the farm households, there is shortage in the colony from February to the fourth week of June if there is no *Belg* rain. According to the survey results, almost more than half of bees feeding practices are undertaken by women than men (Figure 2).

Shading /apiary barn/ construction practices

As shown in Table 8, among the total number of respondents, 75.7% constructed apiary barn and the remaining 24.3 % did not. Among those who constructed apiary barn, 65% constructed the barn separately for each hive and 35% did so in a non-separated manner. Among the respondents, 67.5% of the farm households set the direction of the apiary barn east to west, which enables the bee colony to get sunlight in the morning. 7.1% set the direction of the apiary site west to east. Their reason was to protect the apiary from wind; 10.4% of the respondents set some of the bee colonies in an east-west direction, and some other bee colonies are set in a north, south direction and their justification is to protect the bee colonies from fighting with one another.

Honey bee flora plantation practices

According to Abebe *et al.* (2016), over 80 plant species for honey bee flora were investigated in Wag-Lasta area. However, the sample households do not plant honeybee flora due to lack of awareness and honey bee flora seedling. The natural bee forage is seasonal and, hence, feed shortage occurs in some months of the year, especially from January to June.

Honey marketing

Table 9 reveals that 91.4% of the respondents produce honey primarily for market and the remaining 8.6% produce it for home consumption. Moreover, the average price of crude honey was 95 *birr*/kg, 75 *birr*/kg, 150 *birr*/kg, 65 *birr*/kg and 100 *birr*/kg in the local markets of Sekota, Asketema, Ziquala, Bugna and Lalibela, respectively, at honey harvesting time. The sample households sold on average 38.34kg crude honey and got 2921.9 *birr* per household in the 2015 production year (Table 10).

Comparative advantages of modern beehives over traditional beehives

High yield, better honey quality, ease of inspection, and ease of product harvesting are the major relative advantages of modern beehives over traditional ones as identified by the majority of bee-keepers that took part in the group discussion, provided all modern beehive technology packages are fulfilled. On the other hand, the high cost of the hive and other equipment and accessories, the high level skill requirement, the need for improved bee equipment and accessories, vulnerability to pests and predators, as well as the demand for sunlight and additional labor are the key relative disadvantages of the modern beehive as identified by the majority of respondents in the group discussion. On the other hand, the traditional beehive has various drawbacks. Some of them are low honey yield and quality, difficulty in inspection and harvesting, and short life-span (it breaks by rain). However, the traditional beehive has an advantage as it is a source of colony multiplication and its cost is low. During the focus group discussion on modern beehive adoption, the group members stated that the modern beehive (frame hive) is not suitable to bee colonies, as the bee colonies stay in these hives for a short period of time -

one or two years. Otherwise, according to the ideas expressed in the group discussion and the researcher's personal observation, there are different opportunities to disseminate and upgrade the bee-keeping sector in the study area. Those are: diversified and good quality honey bee flora, environmental friendliness of the sector, and attention given by the government to the bee-keeping sector. (Wag-Himra zone is identified for its apiculture and small ruminant development potential.)

Farmers' perception of modern beehive technology

Farmers strongly agreed that modern beehive technology gives high quality honey yield (51.5%); that modern beehive technology improves honey yield production and productivity (43.9%), that modern hive bee-keeping is more profitable as compared to the traditional one (21.6%); and that the technology is easy to understand and implement (13.5%). On the other hand, 20.5% of the farmers strongly disagreed, 29.2% disagreed, and 21.1% were not decided on the statement that modern beehive technology is not vulnerable to different bee diseases. The reason behind such a response was that the farmers could not distinguish between the three beehive types due to lack of technical skills. As the $\chi 2$ result shown in Table 9, the observed frequencies across categories depart significantly from the expected homogeneous distribution. However, farmers' participation in modern beehive technology utilization is not as high as expected. This is due to the thinking that farmers' commitment, skills in modern beehive technology packages, dependency on aid of NGOs, lack of individual extension services and follow-up of the experts, and supply of all the necessary equipment and accessories declined from year to year. As depicted in Table 9, the mean score of each Likert item is less than 3.5 except for Likert items 1.1 and 3.2. This indicates that the level of adoption of modern beehive technology of bee-keepers was minimal. The possible reasons for the minimum adoption of modern beehives are, as indicated in Table 9, complexity of technology, absence of sufficient training, deficiency of extension support and services, and lack of bee-keeping equipment and accessories (which are expensive) in the right time (Table 11).

Results of the econometric models

Based on the log-likelihood values of the two models estimated, the LR-test results suggest the rejection of the Tobit model. That is, the test statistic Γ = exceeds the critical value of the χ2 distribution (Table 12). Estimates of the parameters of the variables expected to have an effect on the decision to adopt and the intensity of use of modern beehive technology are incorporated into the double hurdle model. Among those variables, 9 significantly influence the probability of adoption decision and 6 variables statistically affect the intensity of use of modern beehives. Heteroscedasticity problem was corrected by the use of command *robust* in STATA (version 12). The multicollinearity problem was checked by using VIF (Variable Inflation Factor) for continuous and dummy variables and there is no serious problem with the mean VIF value of 10.33.

Number of traditional beehives possessed

The results from the econometric model show that the number of traditional beehives possessed by bee-keepers negatively limits both the probability of adoption decision and the intensity of use of modern beehives at 1% significant level. It may be argued that bee-keepers who own large numbers of traditional beehives are reluctant to use large numbers of modern beehives; they would rather experiment with small numbers of modern beehives to compare the honey yield between modern and tradition beehives (Table 13).

Access to credit service

Access to credit had a positive effect on first hurdle at 10% and second hurdle at 5% significant level. As the credit service provision of the bee-keepers changed, modern beehive use intensity increased by 20.7%. The reason behind this result may be that credit service minimizes the financial constraints of bee-keepers and enables them to obtain modern beehives (Table 13).

Distance of bee-keepers residence from Woreda agriculture office

The distance of bee-keepers residence from Woreda agriculture offices negatively limited modern beehive use intensity at 1% significant level. A one-kilometer distance of the farmers' residence from the Woreda agriculture office decreased modern beehive use intensity by 0.91%. The fact behind this result is that farmers who are far from Woreda agriculture office could not easily access the modern beehive technologies (Table 13).

Training access

Access to training positively influenced the probability of adoption decision of modern beehive at 1% significant level; however, it negatively affected the use intensity of modern beehives at 5% significant level, which was unexpected. The justification behind this might be that participation in bee-keeping training initially increased the probability of adoption decision of modern beehives. But the farmers participated in the training only for the per diem they got during training rather than using modern beehives (Table 13).

Age of the respondents

As regards the age of the bee-keepers, it can be observed that age has a parabolic effect on the level of modern beehive adoption with a turning point of 47 years; it has no influence on the probability of adoption decision of modern beehives, though. Age negatively influenced modern beehive use intensity at a 5% significant level. This indicates that farmers aged above 47 years are most likely to have a lower level of modern beehive use for fear of absconding, tedious management, and other risks. As the age of bee-keepers increases, the desire to increase the number of modern beehives decreases (Table 13).

Participation in off-farm activity

Participation in off-farm activities other than bee-keeping positively affected the probability of adoption decision at 1% significant level, but it influenced the use of intensity of modern beehives negatively. The reason behind this might be that farmers who participated in other off-farm activities earned additional incomes and acquired improved technologies. As a result, they are more probably to decide to adopt modern beehives. Nevertheless, this might not be true for intensity of use of modern beehives. This result is in line with Birhanu *et al.* (2014) (Table 13).

Annual income and livestock holding as well as extension service and educational status of the sample bee-keepers positively affected the probability of adoption decision; however, they did not influence modern beehive use intensity (Table 13). Moreover, annual income, livestock holding, extension service and educational status of the sample beekeepers have significant mean difference and association between adopters and non-adopters with t-test and χ2-test (Table 2 and 3).

5. Conclusions and Recommendations

5.1 Conclusions

Even though the government of Ethiopia gives great attention to the bee-keeping sub-sector to promote modern bee-keeping technologies, the probability of adoption and use intensity of modern beehives is found to be minimal. Pests and predators, drought, and lack of bee equipment and accessories are ranked as the first, second and third major constraints of bee-keepers, respectively. Moreover, age, number of livestock owned, educational level of farmers, number of local hives bee-keepers possessed, training provided, total annual income of bee-keepers, credit service, distance to Kebele agricultural office, extension service, and participation in off-farm income sources are the main determinants of the probability of adoption and use intensity of modern beehives in north Wollo and Wag Himra zones.

5.2 Recommendations

Based on the conclusions, the following recommendations are drawn:

- ✓ Bee-keeping equipment and accessories have to be supplied or made accessible to the farmers and great attention has to be given to increase productivity and to take appropriate management practices of modern beehives which can positively affect the probability of adoption and use intensity of modern beehives.
- ✓ Credit service enables farmers to solve their financial constraints. Therefore, it should be provided to bee-keepers to widen the financial bases of poor bee-keepers. Bee-keepers can use the loan to buy modern beehives and have access to modern beehive equipment and accessories like honey extractor, wax stumper, queen excluder, smokers, brush, gloves, bee veil, and others.
- ✓ Adequate training has to be provided to farm households both practically and theoretically. Also, training has to be given focusing on timely

application of using different chemicals, specifically herbicides, to minimize the shortage of honey bees.

- ✓ Agricultural extension services have to be provided to farm households including those farmers who are far from development agent offices.
- ✓ Appropriate prevention and controlling methods of pests and predators, especially wax moth and birds, have to be further studied by biological researchers. Also, appropriate coping mechanisms for bee-keeping during drought have to be further studied by biological researchers.

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Annex

Table 1: List of dependent and independent variables employed in double hurdle model

Variables	SPSS Code	Type	Measurement	Expected sign
Adoption decision of modern beehive	ImprBHive	Dummy	Adopter = 1 and non-adopter = 0	---
Proportion of modern beehive holding	ProportionFH	Continues	Number	----
Sex of respondents	Sex	Dummy	Male = 1, female = 0	+ve
Age of respondents	Age	Continues	Number of years	-ve
Education level of respondents	Educ	Dummy	Literate = 1, illiterate = 0	+ve
Number of family labor of the respondents	FamLabor	Continues	In terms of man equivalent	+ve
Total farm land	TFland	Continues	Measured in hectare	+ve
Livestock holding of respondents	LivstockHold	Continues	Measured in TLU	+ve
Supplementary feeding	Suppfeed	Dummy	Yes = 1 and No = 0	+ve
Number of traditional beehive	NoTdH2007	Continues	Measured in number	+ve
Beekeeping experience with modern beehive	HLKFrHive	Continues	Measured in number of years	+ve
Participation in off-farm activities	OffarmActv	Dummy	Yes = 1 and 0 = No	+ve/-ve
Total annual income	TAnuIncom	Continues	Measured in Ethiopian birr	+ve
Access to extension services	EXT	Dummy	Yes = 1 and No = 0	+ve
Training on beekeeping	Traing	Dummy	Yes = 1 and No = 0	+ve
Access to credit	Credit	Dummy	User = 1 and otherwise = 0	+ve
Distance to kebelle Agriculture office of respondents' residential	DistKAO	Continues	Measured in kilometers	-ve
Distance to woreda Agriculture office of respondents' residential	DisWorO	Continues	Measured in kilometers	-ve

Table 2: Demographic and socioeconomics characteristics of respondents (Categorical and Nominal variables).

		Adopters	Non Adopters	Total	¡2	Asymp.sig
Sex of respondents	Female	8	4	12 (4.5)	0.045	0.833NS
	Male	163	93	171(95.5)		
	Total	171	97	268(100)		
Level of education of the respondents	Illiterate	69	65	134(50)	23.933	.000***
	spiritual education	7	7	14(5.2)		
	adult education	29	6	35(13.1)		
	primary education	54	18	72(26.9)		
	secondary education	12	1	13(4.9)		
	Total	171	97	268(100)		
Are you a member of community organizations?	Yes	164	92	256(95.5)	.163	.686NS
	No	7	5	12(4.5)		
	Total	171	97	268(100)		
Do you participate in formal institutions?	Yes	116	54	170(63.4)	3.949	0.047**
	No	55	43	98(36.6)		
	Total	170	98	2689100)		
Have you got extension services about modern beehive technology?	Yes	121	30	151(56.3)	39.922	.000***
	No	50	67	117(43.7)		
	Total	171	97	268(100)		

Have you ever participated on modern beehive technology training?	Yes	125	24	149(55.6)	58.626	.000***
	No	46	73	119(44.4)		
	Total	171	97	268(100)		
Have you ever used credit for beekeeping?	Yes	29	4	33(87.7)	9.444	0.002***
	No	142	93	235(12.3)		
	Total	171	97	268(100)		
Do you participate in off farm activities?	Yes	101	37	138(48.5)	10.844	.001***
	No	70	60	130(51.5)		
	Total	171	97			
Do you supplement feed for bee colony?	Yes	60	0	60(22.4)	43.853	.000***
	No	111	97	208(77.6)		
	Total	171	0	268(100)		
Do you give water for bee’s colony?	No	39	23	62(23.1)	0.028	0.866NS
	Yes	132	74	206(76.9)		
	Total	171	97	268(100)		
Did you plant bee forage?	Yes	68	0	68(25.4)	51.688	.000***
	No	103	97	200(74.6)		
	Total	171	97	268(100)		
Do you change combs of modern frame hive?	Yes	89	0	89(33.2)	75.587	.000***
	No	82	97	179(66.8)		
	Total	171	97	268(100)		

*** and ** shows the level of significance at less than 1 % and 5%; The numbers in brackets are standard errors of mean and the bracket indicates the percentage of the respondents of the parameters. And also NS is Non Significant.

Table 3: Demographic and socioeconomics characteristics of continuous explanatory variables

Variables	Mean			t-value	Sign.
	Adopters	Non- adopters	Combined		
Age of the respondents.	46.88	50.02	48(.81)	-1.87	(.063)*
Number of family labor of the household in man equivalent.	2.86	2.99	2.9(.07)	-.93	(.355)
Total amount of farm land in hectare	.89	.77	.84(.03)	1.96	(.051)**
Number of livestock owning of the household in TLU.	5.73	4.12	5.15(.19)	4.06	(.000)***
Number of traditional hive you keep	7.22	4.25	6.14(.52)	2.81	(.005)***
How far is the kebelle agricultural office?	3.02	4.19	3.44(.19)	-2.94	(.004)***
How far is the woreda agricultural office?	16.97	16.78	16.9(.55)	.17	(.867)
Total annual income of the household	31924.8	22873.52	28648.77(696.2)	6.75	(.000)***
Amount of honey yield harvested per colony from frame hive	13.55	-	-	-	-
Amount of honey yield harvested per colony from transitional hive	11.26	-	-	-	-
mount of honey yield harvested per colony from traditional hive	4.45	4.24	4.36(.18)	.593	(.554)

***, **, and * show the level of significance at 1, 5 and 10% respectively; the numbers in brackets are mean standard error.

Table 4: Two years data on honey yield productivity per each type of hive

Type of beehive with production year	Minimum	Maximum	Mean	Std. Dev.
Amount of harvested yield in kg per frame hive in 2006	8.5	26.0	14.3	3.5
Amount of harvested yield in kg per frame hive in 2007	8.0	21.0	13.5	3.3
Amount of harvested yield in kg per transitional hive in 2006	7.0	18.0	11.1	4.0
Amount of harvested yield in kg per transitional hive in 2007	7.5	19.0	11.3	3.5
Amount of harvested yield in kg per traditional hive in 2006	0.0	15.0	4.9	2.5
Amount of harvested yield in kg per traditional hive in 2007	0.0	15.0	4.4	2.7

Table 5: Major constraints of beekeeping in the study area

	Frequency	Percent
pests and predators	118	44.0
shortage of bee forage	9	3.4
lack of extension support	6	2.2
Drought	55	20.5
indiscriminate chemical application	22	8.2
lack of bee equipment	36	13.4
beekeeping skill	11	4.1
poor technology compatibility	1	.4
tough management package	3	1.1
financial problem	7	2.6
Total	268	100.0

Table 6: Major constraints of beekeeping in the study area in rank

	Frequency	Percent
Ant	86	32.1
wax moth	82	30.6
honey badger (megoza)	3	1.1
Birds	79	29.5
Spider	14	5.2
Lizard	4	1.5
Total	268	100.0

Table 7: The distribution of modern beehive and reasons for discontinuing of modern bee hive

		Frequency	Percent
Do you use modern beehives?	No	97	36.2
	Yes	171	63.8
	Total	268	100.0
Did you discontinue frame hive production?	No	136	79.5
	Yes	35	20.5
	Total	171	100
If yes, why do you discontinue frame hive production+?	Tough hive management	1	2.9
	pest occurrence (typically wax moth)	14	40.0
	Lack of inputs (wax, reconstructing material , smoker etc)	1	2.9
	Lack of skills (wax casting, honey harvesting, honey extracting, etc)	1	2.9
	Pest occurrence and lack of inputs	4	11.4
	Absconding	12	34.3
	Drought	2	5.7
	Total	35	100.0
If you discontinued frame hive, for what purpose the equipment use it?	putting for clothes as a box	9	25.7
	for using as sitting chair	2	5.7
	for used as fuel wood	1	2.9
	for using as a coffee pot sitting	3	8.6
	simply stored in the house	20	57.1
	Total	35	100.0

Table 8: Shading construction, direction of apiary barn, reasons to set the direction and not constructing apiary shade

		Frequency	Percent
Do you have apiary barn (bed, floor, shade) for bee hives?	No	65	24.3
	Yes	203	75.7
	Total	268	100.0
If yes, from which material did you prepare the shade?	grass, stone and wood	191	94.1
	Iron sheet	12	5.9
	Total	203	100.0
If yes, how the apiary barn prepared?	non-separated	71	35.0
	Separated	132	65.0
	Total	203	100.0
If yes, the direction of apiary barn?	east to west	181	67.5
	west to east	19	7.1
	north to south	38	14.2
	south to north	2	.7
	west to east and south to north	28	10.4
	Total	268	100.0
Why you make the direction of apiary barn the above one?	to protect from wind	29	10.8
	suitable for collecting nectar	42	15.7
	to water source direction	3	1.1
	cultural influence	28	10.4
	to get morning sunlight earlier	125	46.6
	decrease the conflict with each other	17	6.3
	all except cultural influence	9	3.4
	protect from sunlight	15	5.6
	Total	268	100.0
If no, why did not construct apiary barn?	cost of construction	14	21.5
	Ignorance	34	52.3
	perception problem	17	26.2
	Total	65	100.0

Table 9: Percentage of honey to sold into the market

		Frequency	Percent
Do you sale honey in 2015 year?	no	23	8.6
	yes	245	91.4
	Total	268	100.0

Table 10: Income gained from honey sold and amount of honey sold in 2015

	N	Minimum	Maximum	Sum	Mean	Std. Dev.
Total volume of honey sold in kg for from the three hives in the 2015	217	.0	360.0	8320.0	38.341	50.3176
Total income gained in birr for honey sold from the three hives in the 2015	218	.00	19400.00	636969.00	2921.8761	3510.79193

Table 11: Farmers perception on modern beehive technology

Likert items	Strongly disagree		Disagree		Not decided		Agree		Strongly agree		Mean Score	χ^2-test
	N	%	N	%	N	%	N	%	N	%		
Concerning technology compatibility												
Modern hive beekeeping is profitable as compared to traditional hive.	33	19.3	46	26.9	1	0.6	54	31.6	37	21.6	3.1	48.035 (0.000)
Management of modern hive is not difficult as compared to traditional hive.	35	20.5	53	31	-	-	83	48.5	-	-	2.8	20.632 (0.000)
Modern beehive technology does not need expensive equipments and accessories.	111	64.9	58	33.9	1	0.6	-	-	1	0.6	1.4	195.947 (0.000)
Modern beehive technology gives high quality honey yield.	5	2.9	-	-	2	1.2	76	44.4	88	51.5	4.4	145.936 (0.000)
Modern beehive technology is not vulnerable to different bee diseases.	35	20.5	50	29.2	36	21.1	50	29.2	-	-	2.6	4.930 (0.177) NS
Modern beehive technology is not vulnerable to different bee pest.	-	-	39	22.8	112	65.5	20	11.7	-	-	2.9	82.772(0.000)
Modern beehive technology is not labor intensive.	33	19.3	76	44.4	15	8.8	47	27.5	-	-	2.4	46.520 (0.000)
Concerning training provided												
The training provided was practical and theoretical concerning improved management package of modern beehive technology.	21	12.3	31	18.1	-	-	109	63.7	10	5.8	3.3	142.053 (0.000)
The training improves your modern bee keeping management skill and knowledge.	61	35.7	44	25.7	13	7.6	53	31	-	-	2.3	30.988 (0.000)
Concerning the extension services												
The follow up of experts help you apply improved management package were good.	55	32.4	66	38.8	6	3.5	41	24.1	2	1.2	2.2	97.706 (0.000)
The modern beehive technology improves honey yield production and productivity.	-	-	10	5.8	-	-	86	50.3	75	43.9	4.3	59.193 (0.000)
The modern beehive technology gives high wax yield production and productivity.	9	5.3	152	88.9	6	3.5	4	2.3	-	-	2.0	372.556 (0.000)
The technology was easy to understand and implement.	15	8.8	40	23.4	3	1.8	90	52.6	23	13.5	3.4	134.936 (0.000)
The absconding rate of modern beehive is low as compare to traditional beehive.	38	22.2	112	65.5	3	1.8	18	10.5	-	-	2.0	163.994 (0.000)
Concerning the sustainability of the technology usage												
You will adopt the technology in the future.	26	15.2	35	20.5	54	31.6	54	31.6	2	1.2	2.8	55.228 (0.000)
You will tell to your neighbors' and other farmers about the merit of the technology.	30	17.5	77	45	43	25.1	21	12.3	-	-	2.3	42.310 (0.000)

Table 12: Test of double-hurdle model versus Tobit model

	Tobit, $0 \leq Y \leq 1$	Probit, D	Truncated Regression, (Y>0)
LOG-L	-139.837	-97.804	33.998
Number of observation (N)	268	268	136
Double-hurdle versus Tobit test statistic: $\Gamma = 152.062 > \chi^2 0.01,17 = 33.409$			

Table 13: Maximum likelihood estimation of double-hurdle model of adoption decision and intensity use of modern beehive technology.

Variables	Probit model result				Truncated regression result		
	Coefficients	Robust Std. Err.	P – value	Marginal Effect	Coefficients	Robust Std. Err.	P - value
Sex	-.282058	.3886472	0.468	-.0893783	.1470069	.117739	0.212
Age	-.0003844	.0515471	0.994	-.000132	.043803	.0196082	0.025
Age2	-.0002374	.0005094	0.641	-.0000815	-.0004633	.000209	0.027
FamLabor	.205767	.0903976	0.023	.0706591	-.0205384	.0265964	0.440
Educ	.4676153	.2371266	0.049	.1589555	.0178647	.0536641	0.739
TFland	.1797264	.2597785	0.489	.0617169	-.0439899	.0509018	0.387
LivstockHold	.0983316	.0384715	0.011	.0337664	-.0077746	.0080526	0.334
Suppfeed	.1664784	.2383377	0.485	.0559515	-.0423402	.053151	0.426
NoTdH2007	.0533955	.0195905	0.006	.0183357	-.0366384	.0066278	0.000
HLKFrHive					-.0060097	.0073341	0.413
DistKAO	-.042388	.0339281	0.212	-.0145558	-.003469	.0083313	0.677
DisWorO	-.0066131	.012012	0.582	-.0022709	-.0090828	.0031311	0.004
EXT	.7044103	.2113232	0.001	.2438583	.0597975	.0612544	0.329
Traing	1.011333	.2071388	0.000	.3463866	-.1385142	.071543	0.053
Credit	.7118622	.4300433	0.098	.2021387	.2069757	.0820266	0.012
OffarmActv	.6424252	.2318289	0.006	.2190727	-.0479963	.0587648	0.414
TAnuIncom	.0000419	.0000116	0.000	.0000144	3.05e-06	2.87e-06	0.287
Cons	-2.78572	1.361036	0.041		-.1578401	.4570117	0.730
sigma					.2475725	.0158073	0.000

Number of obs. = 268
Log- L = -97.804359
Wald chi2 (16) = 112.82
Prob. > chi2 = 0.0000
Pseudo R2 = 0.4424
Correctly predicted = 70.8%P = predicted value

Number of obs = 136
Log- L = 33.998286
Wald chi2 (17) = 101.48
Prob. > chi2 = 0.0000
Limit: lower = 0, upper = +inf
correctly predicted = 36.2%P

Figure 1: Map of the study area

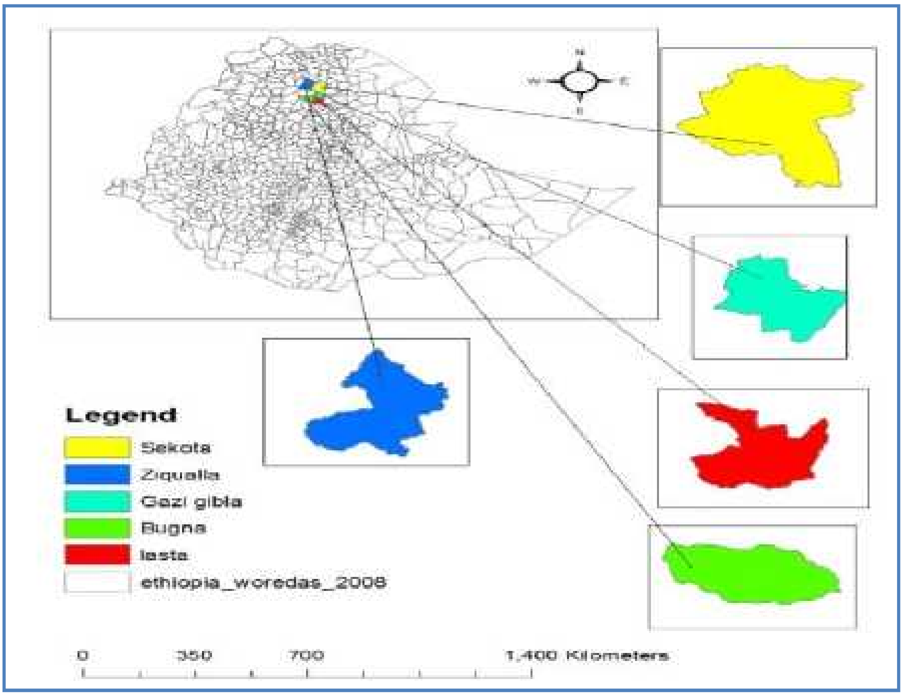

Figure 2: The responsibility of family members who follow up / inspection and hygiene, honey harvesting, give water & supplementary feeding, to the bee colony