Determinants of beekeeping adoption by smallholder rural households in Northwest Ethiopia

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Abstract: There is an enormous potential for beekeeping practices to generate income, create jobs, and alleviate poverty. However, in Ethiopia, there are many constraints that hinder rural households to expand and adopt beekeeping practices. The objective of this study was to analyze the determinants of beekeeping adoption in Northwest Ethiopia. To achieve the objective, cross-sectional data were collected from 369 rural households and analyzed using a nonlinear econometric (binary logistic regression) model. The maximum likelihood estimation results revealed that sex, marital status, household size, and the educational status of the household head, number of extension visits, membership in a farmers’ association, and access to credit were the statistically significant variables determining beekeeping adoption in the study area. The beekeeping constraints that had statistically significant influence on beekeeping adoption were grouped as marketing, natural, and financial. To reap the benefits from the huge potential of honeybee colonies, the government of Ethiopia and other associated actors and stakeholders should work together to solve the constraints faced by rural households in adopting beekeeping practices that could result in improving their livelihoods.

Subjects: Econometrics; Development Economics; Production, Operations & Information Management; Marketing

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PUBLIC INTEREST STATEMENT
Ethiopia has many honeybee colonies that bring great potential for honey production. But the number of beekeeper households who practice beekeeping and honey production is below its potential. It is possible to reap the benefits of a large number of bee colonies by improving the participation of farmers in beekeeping. In Ethiopia, studies have shown that beekeeping adoption is influenced by many constraints. However, there is a lack of studies conducted to identify beekeeping constraints and measure their impact on beekeeping adoption by smallholder farmers. Hence, this study was conducted to fill this gap. This will help governmental and non-governmental organizations to focus on solving the constraints and factors influencing beekeeping adoption to improve the benefits obtained from beekeeping activities.
Keywords: beekeeping adoption; rural households; Logit model; constraints; honeybee

1. Introduction

Beekeeping has been promoted globally for increasing income, reducing poverty, and improving livelihoods (Schouten, 2021). The Codex Alimentarius defines honey as “the natural sweet substance produced by honeybees from the nectar of plants or from secretions of living parts of plants or excretions of plant sucking insects on the living parts of plants, which the bees collect, transform by combining with specific substances of their own, deposit, dehydrate, store and leave in the honeycomb to ripen and mature” (Codex Alimentarius Commission, 1981).

The income generated from beekeeping activities can be used to pay for social services such as education, health, transport, and housing; and beekeeping provides employment for both urban and rural people (Hauser & Mpuya, 2004). Beekeeping also generates a variety of productive assets that can improve the livelihoods of rural communities (Qaiser et al., 2013). Beekeeping plays a role in generating and diversifying the income of Ethiopian smallholder farmers (Beyene et al., 2016). Ethiopia is blessed with a variety of agro-climatic conditions and biodiversity that promote the presence of diversified honeybee flora and a massive number of honeybee colonies (Adgaba, 2007). According to the Central Statistical Agency (CSA) data, Ethiopia has the largest bee population in Africa with over 10 million bee colonies, out of which about 4.6 million are in hives and the remaining are in forests (CSA, 2007). This makes Ethiopia a leading country in Africa and the ninth in the World in honey production. Beekeeping subsector is dominantly for small-scale farmers and is making a significant contribution by increasing off-farm income and reducing poverty in rural areas of Ethiopia (MoARD, 2007). Honey is considered as a cash crop and only around 10% of the honey produced in Ethiopia is consumed by the beekeeping households and the remaining 90% is sold for income generation (Hartmann, 2004).

Beekeeping activity is carried out in most parts of Amhara Region, the region where this study was conducted. About 45% of its agro ecology is characterized as midland (altitude of 1500–2300 m.a.s.l.), which is more appropriate for commercial beekeeping. Diversified agro-ecologies (altitudes ranging from 500 to 4620 m.a.s.l.), the presence of active and engaging non-governmental organizations (NGOs), the establishment of Lalibela National Apiculture Museum, the presence of Jarie and Gorgora queen rearing, and the beekeeping training centers made the region ideal for honey production (EAB, 2016).

Although there is an enormous potential for beekeeping practices to generate income, create jobs, and alleviate poverty, there are many constraints that hinder rural households from adopting and expanding beekeeping practices. Therefore, it is necessary to identify the constraints faced by rural households to adopt beekeeping practices. Several studies were conducted in different countries on the beekeeping sector. For example, the study by Amulen et al. (2017) identified the key drivers and barriers (constraints) of beekeeping adoption at the household level in three agro-ecological zones in Uganda; and the study by Wagner et al. (2019) identified key drivers and barriers to beekeeping adoption in four communities in central Tanzania. However, there are limited studies conducted in Ethiopia that identified the determinants of beekeeping adoption and the influence of constraints that hinder rural households to participate in the beekeeping sector. For example, the study conducted by Tulu et al. (2020) focused on the use and adoption rate of improved beekeeping technology in Southwestern Ethiopia; but the study did not identify the factors and constraints that hinder the non-beekeepers from participating in the beekeeping sector.

Wakagri and Yigezu (2021) reviewed honeybee production constraints and important management practices to address the constraints. But the study did not examine which constraints have high influence on honey, honeybee, and its valuable products. Other studies such as Adgaba et al. (2014), Tarekegn et al. (2017), Molineri et al. (2018), Goodrich (2019), Yeserah et al. (2019), and
Andaregie & Astatkie, Cogent Food & Agriculture (2021), 7: 1954817
https://doi.org/10.1080/23311932.2021.1954817

Underwood et al. (2019) focused on different aspects of the beekeeping sector. However, these studies did not examine the effect of various constraints on beekeeping adoption, particularly by smallholder rural households. Therefore, to help with alleviating poverty and improving livelihoods, the study aimed to identify the constraints and determinants of beekeeping adoption in Northwest Ethiopia using Principal Component Analysis (PCA) and binary logistic regression modelling.

2. Materials and methods

2.1. Sampling technique and sample size

The target population of this study contained all rural smallholder households in Dangila district of Northwest Ethiopia. According to Awi Administrative Zone Agriculture office, in 2019, there were a total of 16 kebeles (equivalent to counties) with a total population of 24,345 rural smallholder households in Dangila district. Among this total population, the number of beekeepers (adopters) is 3,000 households, and that of non-beekeepers (non-adopters) is 21,345 households. Since these 16 kebeles are internally heterogeneous and externally homogenous in terms factors affecting beekeeping, a two-stage sampling method was used. In the first stage where cluster sampling method was used, four kebeles (Gumdri, Zunga, Washa, and Gissa) that have 991 (Gumdri = 244; Zunga = 252; Washa = 230 and Gissa = 265) adopters, and 3720 (Gumdri = 960; Zunga = 820; Washa = 1020; Gissa = 920) non-adopters were selected randomly. The combined population size of adopters and non-adopters in these four kebeles was $N = 4711$. For the second stage where simple random sampling method was used, the sample size ($n$) was determined as described in Yamane (1967) using the following formula.

$$n = \frac{N}{1 + N(e)^2} = \frac{4711}{1 + 4711(0.05)^2} = \frac{4711}{12.7775} = 369$$

Hence, the total sample size $n = 369$ was allocated to adopters ($n_1 = 78 = \frac{369}{4711} \times 991$) and non-adopters ($n_2 = 291 = \frac{369}{4711} \times 3720$) and to each of the four kebeles proportionally. Then, a structured questionnaire that would allow the collection of demographic, socio-economic, and institutional characteristics of beekeepers and non-beekeepers and constraints for beekeeping practices was developed and used to collect data via personal interviews of all 369 randomly selected smallholder beekeeping adopter and non-adopter households. The respondents were informed about the nature of the study and any risk of harm it might bring to them and were asked to give their informed consent before the interview.

2.2. Method of data analysis

To determine the significance of the associations between two categorical variables, $\chi^2$ (Chi-square) test of independence was conducted. To analyze the determinants of and constraints for beekeeping adoption, two sets of models were applied. These are principal component analysis (PCA) technique and binary logistic regression model. PCA is a data reduction technique that reduces large number of synthetic variables into meaningful smaller components so that the smaller components can be used as explanatory variables in the subsequent binary logistic regression model. PCA technique was used to reduce the large number of constraints for beekeeping adoption into a smaller set of constraints. For the binary Logistic regression model, the dependent variable was beekeeping adoption whose values are binary (either yes = 1 or no = 0).

2.2.1. Principal component analysis (PCA) as a data reduction technique

The central idea of PCA is to reduce the dimension of a data set consisting of a large number of interrelated variables, while retaining the variation present in the data set as much as possible (Jolliffe, 2002). This is achieved by transforming to a new set of variables, the principal components (PCs), which are uncorrelated and ordered according to the percentage of their retention of the variability in the original variables (Jolliffe, 2002). Since using a regression model with many independent variables that are highly correlated with each other will not return the best estimators (Smith & Sasaki, 1979) due to multicollinearity phenomenon, PCA is recommended. This is
because the PCs are orthogonal and a few of them jointly explain a large part of the variation (Hastie et al., 2009). There are many extraction rules and approaches in the determination of the number of components that are to be retained. The most popular one is Kaiser’s criteria, which states that only those PCs with >1 eigenvalue will be retained in the model (Kaiser, 1960). Also, the cumulative percent of variance explained could be used (Williams et al., 2010). Orthogonal Varimax rotational method which maximizes high item loadings and minimizes low item loadings was used.

In this study, the PCA incorporated 47 constraints that can influence beekeeping adoption. For each constraint, a numerical scale with five levels was used (1 = not a constraint and 5 = severe constraint). Although some or all these variables could be correlated, PCA reduces the number of constraints that influence beekeeping adoption to a small number of components that are not correlated. In this study, it means reducing the initial set of 47 variables to five PCs. For example, from a set of variables $X_1$ to $X_{47}$,

$$PC_1 = \alpha_{11}X_1 + \alpha_{12}X_2 + \ldots + \alpha_{1n}X_n$$
$$PC_5 = \alpha_{51}X_1 + \alpha_{52}X_2 + \ldots + \alpha_{5n}X_n$$

(1)

Where, $\alpha_{in}$ represents the weight/component loading for the fifth PC and the 47th initial variable. The weights/ loadings for each PC are given by the eigenvectors of the correlation matrix.

Respondents were asked to rank a list of beekeeping constraints in a 5-Point-Likert scale (1 = “Not a constraint”; 2 = “Minor constraint”; 3 = “moderate constraint”; 4 = “Major constraint”; 5 = “Severe constraint”). The constraints for beekeeping practices were extracted from different literatures and from personal observations. The codes and the descriptions of the constraints for beekeeping adoption are shown in Table 1.

2.2.2. Binary logistic regression model
The second model used to analyze the determinants of beekeeping adoption is binary logistic regression model, which is one of the non-linear econometric models applied when the dependent variable has dichotomous outcome. According to Gujarati (1998), binary logistic (Logit) model is extremely flexible and leads to a meaningful interpretation of the results. Logistic regression is a powerful tool for estimating the individual influences of continuous and categorical variables on a qualitative dichotomous dependent variable (Wright, 1995).

Based on Gujarati (1998), the logistic distribution function for the relationship between the probability of the dependent dichotomous variable and several independent variables can be specified as:

$$P_i = E(Y = 1/X_i) = \frac{1}{(1 + e^{-(\beta_0 + \beta_1 x_i)})}$$

(2)

For ease of exposition this can be written as:

$$P_i = \frac{1}{(1 + e^{\beta_z})} = \frac{e^{\beta_z}}{(1 + e^{\beta_z})}$$

(3)

Where $P_i$ is the probability that households adopt beekeeping and its value ranges between 0 and 1, and its non-linearly related to $Z_i$ (i.e. the explanatory variables $X_i$’s). $e^{\beta_z}$ is standard for irrational number e to power of $z$. $(1 - P_i)$ is the probability of non-adopt by the households.

$Z_i$ is a function of k-explanatory and control variables $(X_i)$ which is also expressed as:

$$Z_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_k x_{ik}$$

(4)

Where, $x_1, x_2, \ldots, x_k$ are explanatory variables; $\beta_0$ is the intercept; $\beta_1, \beta_2, \ldots, \beta_k$ are the Logit parameters (slopes) of the equation in the model.
| No. | Code   | Description of beekeeping constraint                                                                 |
|-----|--------|------------------------------------------------------------------------------------------------------|
| 1   | Laruntrc | Less area under tree cover                                                                               |
| 2   | Fiosc | Floral scarcity (when major flora is absent)                                                             |
| 3   | Wropico | Wrongly placed colonies in an apiary (for bees to rear brood and get good food supply)                |
| 4   | Burnst | Burning of straw in nearby areas                                                                       |
| 5   | Usafche | Use of chemicals in agriculture                                                                       |
| 6   | Laawapol | Lack of awareness in pollination                                                                        |
| 7   | Larce | Lack of regional research center                                                                        |
| 8   | Nonavin | Unavailability of infrastructures                                                                      |
| 9   | Latechknw | Lack of technical knowledge for efficient management of bee colonies for higher honey yield        |
| 10  | Insudisma | Insufficient research for diseases management and control                                                  |
| 11  | Conawa | Failure in creating consumer awareness about honey and its products                                      |
| 12  | Defo | De-forestation                                                                                            |
| 13  | Trawha | Traditional way of harvesting and postharvest management                                                 |
| 14  | Lainli | Lack of institutional linkage                                                                           |
| 15  | Woribee | Weak organization representing the interest of the beekeeper                                            |
| 16  | Laskbee | Lack of skill and knowledge of beekeeping                                                               |
| 17  | Higco | Too high collateral requirements needed by financial institutions                                       |
| 18  | Liaccere | Limited access to credit to expand beekeeping practices                                               |
| 19  | Laacfi | Lack of access to financial institutions                                                                 |
| 20  | Endis | Enemies and diseases                                                                                        |
| 21  | Pepre | Pests and predators                                                                                        |
| 22  | Spiders | Spiders                                                                                                 |
| 23  | Wasps | Wasps                                                                                                    |
| 24  | Lizards | Lizards                                                                                                  |
| 25  | Birds | Birds                                                                                                     |
| 26  | Snakes | Snakes                                                                                                    |
| 27  | Seawea | Seasonal weather problem                                                                                  |
| 28  | Showa | Shortage of water                                                                                        |
| 29  | Deaco | Death of colony                                                                                            |
| 30  | Redbeco | Reduction of honeybee colony                                                                             |
| 31  | Shabefo | Shortage of bee forage because of drought                                                                |
| 32  | Lams | Lack of organized marketing system                                                                       |
| 33  | Lcoem | Lack of cooperatively established market system                                                           |
| 34  | Lkfm | Na/lack of knowledge of the final market                                                                  |
| 35  | Pominf | Poor market infrastructure and linkage                                                                    |
| 36  | Wlspb | Weak linkage between producers and buyers                                                                  |
| 37  | Lpbep | Low price of bee products                                                                                |
| 38  | Ldh | Limited demand for honey                                                                                 |
| 39  | Abpack | Absence of packaging                                                                                     |
| 40  | Lbarpo | Lack of bargaining power                                                                                  |
| 41  | Latra | Lack of transport                                                                                         |
| 42  | Lppro | Lack of product promotion                                                                                |
| 43  | Lmsk | Lack of marketing skills                                                                                 |
| 44  | Lacmi | Lack of access to market information                                                                     |

(Continued)
Table 1. (Continued)

| No. | Code  | Description of beekeeping constraint                        |
|-----|-------|-------------------------------------------------------------|
| 45  | Pomac | Poor market access                                          |
| 46  | Lastf | Lack of storage facilities                                  |
| 47  | Intchar  | Intermediate charges (money paid to middlemen)             |

\[ 1 - P_i = \frac{1}{1 + e^{Z_i}} \]  \hspace{1cm} (5)

Thus, the expression \( P_i/1 - P_i \) is known as the odds ratio and can be written as:

\[ P_i/1 - P_i = \left( \frac{e^{Z_i}/1 + e^{Z_i}}{1/1 + e^{Z_i}} \right) \]  \hspace{1cm} (6)

By taking the natural log of equation (6), we can get:

\[ L_i = \ln(P_i/1 - P_i) = Z_i = \beta_0 + \beta_1 x_i \]  \hspace{1cm} (7)

Where, \( L_i \) is natural log of the odds ratio, which is not only linear in \( x_i \) but also linear in the parameters. Finally, by adding the error term \( U_i \), we get the theoretical Logit model given as:

\[ Z_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_k x_{ik} + U_i \]  \hspace{1cm} (8)

The demographic, socio-economic, and institutional variables that were intended to influence the adoption of beekeeping practices were; Sex of the household head (male = 1; Female = 0) (Sex); Age of the household head in years (Age); Marital status of the household head (1 = Single; 2 = Married; 3 = Divorced; 4 = Widowed) (Mrtts); Household size measured in the number of persons in the household (Fmsz); Educational status of the household head (1 = Literate; 0 = Illiterate) (Educ); The number of years the household head is living in the district (Numyr); Number of extension visits (Exten); Membership in a farmers’ association (1 = Yes; 0 = No) (Mem); Access to credit (1 = Yes; 0 = No) (Credi), and Whether the household head produces honey (1 = Yes; 0 = No) (Honeypro).

The collected data from beekeepers and non-beekeepers were entered to and analyzed using STATA (Version 16) software package released in 2019. To estimate the coefficients of the determinants that affect beekeeping adoption, maximum likelihood estimation method was used.

3. Results and discussion

3.1. Demographic and socio-economic characteristics of respondents

The overall average age of both adopters and non-adopters was 42.93 years. The average age of adopters and non-adopters were 42.26 and 43.53 years, respectively. The average household size of adopters and non-adopters were three and five persons, respectively. The overall mean of household size was four persons per family. The association between household size and beekeeping adoption was strongly significant (p < 0.01).

The mean number of years a household head is living in the district for adopters and non-adopters were 42 and 41 years, respectively. However, the association between the number of years a household head lived in a district and beekeeping adoption was not significant. The average number of extension agent visits for adopters and non-adopters were 5 and 2 times, respectively. This difference was also confirmed by the significant association between the number of extension agent visits and beekeeping adoption.
The $\chi^2$ test of independence results between the categorical variables used in this study and beekeeping adoption are shown in Table 2. Among the total of 68% of male headed households, 51% were adopters and 17% were non-adopters. However, among the female headed households (32%), 6% were adopters and the remaining 26% were non-adopters (Table 2). The results showed that a smaller proportion of female headed households are beekeepers compared to male headed households. The $\chi^2$ test also confirmed a significant association between sex of the household head and beekeeping adoption (Table 2).

Regarding the marital status of the household head, 7% and 6% of the adopters and non-adopters, respectively were single; 29% and 11% of the adopters and non-adopters, respectively, were married; 1% and 32% of the adopters and non-adopters were divorced; and 2% and 12% of the adopters and non-adopters were widowed (Table 2). This relationship between marital status and beekeeping adoption was highly significant (Table 2). The educational status of a household head was considered as one of the explanatory variables that can influences beekeeping adoption in the study area. Accordingly, 43% and 57% of the respondents were literate and illiterate, respectively. Among the literates, 40% and 3% of the respondents were adopters and non-adopters, respectively (Table 2). Among the illiterates, 7% and 50% were adopters and non-adopters, respectively (Table 2). The $\chi^2$ test of independence result showed a highly significant ($p < 0.01$) association between educational status of a household head and beekeeping adoption (Table 2).

Membership in a farmers’ association also had a highly significant association with beekeeping adoption (Table 2). Among the members of a farmers’ association, 39% and 7% were adopters and non-adopters, respectively; and among the non-members, 2% and 52% were adopters and non-adopters, respectively (Table 2). Regarding access to credit, among those who have access to credit, 42% and 4% were adopters and non-adopters, respectively; but, among those who did not have access to credit, 5% and 49% were adopters and non-adopters, respectively (Table 2). This relationship was significant. Among the households that process honey produce, 18% and 7% were adopters and non-adopters, respectively (Table 2). On the other hand, among those who did
not process honey produce, 36% and 39% were beekeeping adopters and non-adopters, respectively (Table 2).

3.2. Availability of equipment for honey production and processing
This section presents the descriptive statistics on whether rural households are processing honey produce, and the availability of equipment for honeybee production and processing. Processing refers to the steps from raw harvest to bottling of honey as described in Subramanian et al. (2007). The results showed that 69.9% of rural households did not process honey produce and 30.1% of the households processed honey produce. In the study area, honey processing also includes converting/processing honey to traditional honey bee called Tej (made from mixing honey, Rhamnus prinoides (gesho), and malt).

Table 3 shows descriptive statistics of the percentage of the adopters who have access to equipment for honeybee production and processing. As indicated in Table 3, 52% adopters responded that they did not have harvesting gear and the remaining 48% had harvesting gear. The majority of the respondents (57%) have no sieving equipment for the production of honey and the remaining 43% had (Table 3). Regarding the availability of packaging and transporting, 68% and 67% of the beekeepers did not have packaging and transporting equipment, respectively; whereas 32% and 33% of the adopters had (Table 3).

3.3. Reliability tests and descriptive statistics of beekeeping constraints

3.3.1. Reliability test statistics of the principal components (PCs)
The test statistics that show the reliability of individual PCs and the composite (overall) reliability that confirm the values of the Cronbach’s alpha (α) are greater than the required value are shown in Table 4. According to Cronbach (1951) the recommended standards of the reliability coefficient for the individual PCs is α ≥ 0.6, and for the composite reliability of PCs is α ≥ 0.7. The Cronbach’s α

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**Table 3. Availability of equipment to adopters for honeybee production and processing**

| Equipment needed for activities | Category | Percent |
|---------------------------------|----------|---------|
| Harvesting gear                 | No       | 52%     |
|                                 | Yes      | 48%     |
| Sieving                         | No       | 57%     |
|                                 | Yes      | 43%     |
| Packaging                       | No       | 68%     |
|                                 | Yes      | 32%     |
| Transporting                    | No       | 67%     |
|                                 | Yes      | 33%     |

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**Table 4. Reliability test statistics of principal components**

| Name of principal component     | Number of items (constraints) | Individual reliability (Cronbach’s alpha) | Overall reliability |
|---------------------------------|-------------------------------|------------------------------------------|---------------------|
| Marketing constraints           | 16                            | 0.985                                    |                     |
| Natural constraints             | 12                            | 0.978                                    |                     |
| Honeybee production constraints | 12                            | 0.949                                    | 0.917               |
| Management constraints          | 4                             | 0.992                                    |                     |
| Financial constraints           | 3                             | 0.922                                    |                     |
| Beekeeping constraint | Mean | St. Dev. | Raw Initial | Raw Extracted | Rescaled Initial | Rescaled Extracted |
|-----------------------|------|----------|-------------|---------------|------------------|--------------------|
| Loms                  | 4.33 | 0.706    | 1.491       | 1.456         | 1.000            | 0.976              |
| Lcoern                | 4.11 | 0.767    | 1.490       | 1.480         | 1.000            | 0.993              |
| Lkfm                  | 3.45 | 0.960    | 1.490       | 1.480         | 1.000            | 0.993              |
| Pominf                | 3.73 | 0.993    | 1.513       | 1.379         | 1.000            | 0.912              |
| Wlpb                  | 3.55 | 1.032    | 1.382       | 0.940         | 1.000            | 0.680              |
| Lpbep                 | 2.72 | 0.849    | 1.395       | 0.969         | 1.000            | 0.695              |
| Ldhn                  | 2.37 | 0.862    | 1.564       | 1.164         | 1.000            | 0.744              |
| Abpack                | 4.55 | 0.631    | 1.358       | 0.955         | 1.000            | 0.703              |
| Lbarpo                | 2.93 | 0.731    | 1.704       | 1.264         | 1.000            | 0.742              |
| Ltra                  | 2.70 | 0.742    | 1.490       | 1.480         | 1.000            | 0.993              |
| Lppro                 | 4.14 | 0.777    | 1.381       | 1.213         | 1.000            | 0.878              |
| Lmsk                  | 4.29 | 0.718    | 1.383       | 0.991         | 1.000            | 0.717              |
| Lacmi                 | 3.47 | 1.028    | 1.449       | 1.057         | 1.000            | 0.730              |
| Pomac                 | 3.54 | 1.169    | 1.454       | 1.184         | 1.000            | 0.815              |
| Lastf                 | 1.90 | 0.854    | 1.564       | 1.248         | 1.000            | 0.798              |
| Intchar               | 3.45 | 0.651    | 1.435       | 1.316         | 1.000            | 0.917              |
| Trawha                | 4.18 | 0.838    | 0.827       | 0.618         | 1.000            | 0.748              |
| Lainil                | 4.65 | 0.602    | 1.082       | 1.037         | 1.000            | 0.958              |
| Woribee               | 3.61 | 0.980    | 1.093       | 1.048         | 1.000            | 0.959              |
| Laskbee               | 4.19 | 0.701    | 1.100       | 1.038         | 1.000            | 0.943              |
| Larantrc              | 1.82 | 0.742    | 0.829       | 0.703         | 1.000            | 0.848              |
| Fiasc                 | 3.12 | 0.736    | 0.788       | 0.698         | 1.000            | 0.886              |
| Wroplco               | 3.88 | 0.883    | 1.109       | 0.586         | 1.000            | 0.529              |
| Burnst                | 2.17 | 0.714    | 1.098       | 0.786         | 1.000            | 0.716              |
| Usosofche             | 4.12 | 0.829    | 0.941       | 0.644         | 1.000            | 0.684              |
| Loawapol              | 3.81 | 1.086    | 1.441       | 1.002         | 1.000            | 0.695              |
| Larrce                | 2.11 | 0.701    | 0.788       | 0.583         | 1.000            | 0.740              |
| Nonavin               | 3.39 | 0.660    | 0.941       | 0.665         | 1.000            | 0.706              |
| Latechknw             | 3.38 | 0.768    | 1.076       | 0.758         | 1.000            | 0.704              |
| Insudisma             | 4.35 | 0.891    | 0.945       | 0.711         | 1.000            | 0.752              |
| Conawa                | 3.40 | 0.815    | 0.733       | 0.615         | 1.000            | 0.839              |
| Defo                  | 1.81 | 0.656    | 1.050       | 0.776         | 1.000            | 0.739              |
| Higco                 | 4.56 | 0.695    | 1.152       | 0.855         | 1.000            | 0.742              |
| Liaccre               | 4.41 | 0.648    | 1.273       | 1.101         | 1.000            | 0.865              |
| Laoacfi               | 3.09 | 1.077    | 1.132       | 1.006         | 1.000            | 0.889              |
| Endis                 | 4.07 | 0.928    | 1.294       | 1.283         | 1.000            | 0.991              |
| Peprre                | 3.65 | 1.018    | 1.392       | 1.124         | 1.000            | 0.807              |
| Spiders               | 1.95 | 0.806    | 1.182       | 1.054         | 1.000            | 0.892              |
| Wasps                 | 2.66 | 1.209    | 1.371       | 1.195         | 1.000            | 0.872              |
| Lizards               | 1.33 | 0.559    | 1.569       | 1.097         | 1.000            | 0.699              |
| Birds                 | 2.71 | 0.877    | 1.274       | 1.167         | 1.000            | 0.916              |
| Snakes                | 1.16 | 0.369    | 1.185       | 1.082         | 1.000            | 0.913              |
| Seaweea               | 3.61 | 0.656    | 1.442       | 1.156         | 1.000            | 0.802              |

(Continued)
values were 0.985, 0.978, 0.949, 0.992, and 0.922 for the first, second, third, fourth, and fifth PC, respectively. The overall Cronbach’s a value was 0.917 (Table 4). Therefore, the PCs are reliable indicators of the data set and hence explain a meaningful amount of the variance.

3.3.2. Descriptive statistics of beekeeping constraints

The mean and standard deviation of the constraints for beekeeping based on the 5-Point-Likert Scale measurement are shown in Table 5. The higher the mean of the constraints (near to mean = 5), the more severe its influence is on beekeeping adoption.

The level of influence of individual constraints on beekeeping adoption is different. Lack of institutional linkage (Mean = 4.65), too high collateral requirements needed by financial institutions (Mean = 4.56), absence of packaging (Mean = 4.55), limited access to credit to expand beekeeping practices (Mean = 4.41), insufficient research for disease management and control (Mean = 4.35), lack of organized marketing system (Mean = 4.33), lack of marketing skills (Mean = 4.29), lack of skill and knowledge of beekeeping (Mean = 4.19), traditional way of harvesting and postharvest management (Mean = 4.18), lack of product promotion (Mean = 4.14), and lack of cooperatively established market system (Mean = 4.11) were between major and severe constraints for beekeeping adoption. Wrongly placed colonies in an apiary (Mean = 3.88), lack of awareness in pollination (Mean = 3.81), reduction of honeybee colony (Mean = 3.77), poor market infrastructure, and linkage (Mean = 3.73), weak organization representing the interest of the beekeeper (Mean = 3.61), and poor market access (Mean = 3.54) were between moderate and major constraints influencing beekeeping adoption (Table 5). The remaining constraints were either moderate, or minor, or not a constraint.

3.4. Econometric analysis

3.4.1. Principal component analysis (PCA)

Based on the eigenvalues that show the PCA results, the components whose eigenvalues are >1 were chosen and retained in the model. According to Kaiser’s criterion, this selection of the PCs was further confirmed by using other complementary interpretation criteria including the factor loadings of variables; the percentage of variance accounted for by the selected components, and the interpretability of the resulting factors. The number of PCs derived from 47 constraints were 5, which can be used in the subsequent regression analysis.

3.4.2. Communality

Communality is the total influence of all associated components on a single observed variable. It is the sum of all squared component loadings for all the components related to the observed variable, and this value is like $R^2$ in multiple linear regression models (Abdi & Williams, 2010). For example, for the constraint Loms $= 0.988^2 + 0.003^2 + (-0.014)^2 + (-0.001)^2 + (-0.012)^2 = 0.976$ (under rescaled-extracted column of Table 5). The value ranges from 0 to 1, with 1 indicating the dependent variable can be fully explained by the components, and 0 indicating the dependent variable cannot be explained by any of the components.
3.4.3. Total variability explained

Five principal components were retained based on eigenvalue >1 criterion (Table 1). The five principal components (PCs) explain 28.02%, 21.11%, 18.44%, 7.63%, and 6.77% of the total variability, and jointly the components explain 81.77% of the total variability in beekeeping adoption (Table 6).

3.4.4. The component loadings and principal components (PCs)

A component loading represents correlation between a specific observed constraint and a specific component. They are equivalent to standardized regression coefficients in multiple linear regression. Therefore, each PC was formed based on the loadings of the variables (constraints). Higher loadings of a given constraint indicate higher influence in the formation of a given PC and vice versa. Therefore, the loadings were used to determine which constraints are influential in the formation of a given PC and to assign a meaning or label for the PC.

The five PCs indicated in Table 1 are named or labeled first by observing which variables have higher loadings on each component and then labelling based on the variables that had high loadings to a single component. A loading of \( \geq 0.5 \) is used as a criterion for a given variable to be considered as influential in the formation of a PC (Sharma, 1996). With this framework, the five PCs and the loadings of each variable were categorized as shown in Table 1.

Accordingly, lack of organized marketing system, lack of cooperatively established market system, lack of knowledge of the final market, poor market infrastructure and linkage, weak linkage between producers and buyers, low price of bee products, limited demand for honey, absence of packaging, lack of bargaining power, lack of transport, lack of product promotion, lack of marketing skills, lack of access to market information, poor market access, lack of storage facilities, and intermediate charges were labeled as “marketing constraints”. Enemies and diseases, pests, and predators, spiders, wasps, lizards, birds, snakes, seasonal weather problem, shortage of water, death of colony, reduction of honeybee colony, and shortage of bee forage because of drought were labeled as “natural constraints”. Less area under tree cover, floral scarcity, wrongly placed colonies in an apiary, burning of straw, use of chemicals in agriculture, lack of awareness in pollination, lack of regional research center, unavailability of infrastructures, lack of technical knowledge for efficient management of bee colonies for higher honey yield, insufficient research for disease management and control, and failure in creating consumer awareness about honey and its products were labeled as “constraints for honeybee production”. “Management constraints” included traditional way of harvesting and postharvest management, lack of institutional linkage, weak organization representing the interest of the beekeeper, and lack of skill and knowledge of beekeeping. The other constraints such as too high collateral requirements needed by financial institutions, limited access to credit to expand beekeeping practices and lack of access to financial institutions were labeled as “financial constraints” (Table 1).

3.4.5. Determinants of beekeeping adoption by smallholder households

Results of the maximum likelihood estimation of the binary logistic regression model used to determine the significance of the determinants and of the constraints for beekeeping adoption are shown in Table 7. As indicated in the table, among the 15 explanatory variables, 11 of them significantly influence beekeeping adoption. The likelihood ratio \( \chi^2 \) value was highly significant, which indicates that the model is well fitted.

The positive and significant coefficient of sex of the household head (Table 7) indicates that male headed rural households are more likely to adopt beekeeping practices than female headed rural households. Similar results were also reported in other studies including that by Mushonga et al. (2019) who reported that gender bias is one of the challenges of beekeeping adoption in Rwanda; and that by Amulen et al. (2017) who found out that male farmers were more likely to be beekeepers. The study further revealed the potential for developing beekeeping enterprises (opportunities) is immense provided that women’s participation is encouraged and supported.
Table 6. PCA results that show the magnitude and direction of the contributions of constraints to beekeeping practices

| PC | 1         | 2         | 3         | 4         | 5         |
|----|-----------|-----------|-----------|-----------|-----------|
|    | Eigenvalue | Explained variance | Constraints for beekeeping practices | Constraints for honeybee production | Management constraints | Financial constraints |
|    | 19.426    | 28.02%    | Marketing constraints | Natural constraints | Constraints for honeybee production | Management constraints | Financial constraints |
| Loms | 0.988    | 0.944    | −0.014 | 0.005 | 0.048 | 0.128 |
| Lcom | 0.997    | 0.819    | −0.012 | 0.004 | 0.004 | −0.002 |
| Lkm   | 0.997    | 0.853    | −0.012 | 0.004 | 0.004 | −0.002 |
| Pominf | 0.944 | 0.819 | 0.005 | 0.048 | 0.128 |
| Wtpb | 0.813    | 0.919    | −0.010 | −0.101 | 0.002 |
| Lpbe | 0.819    | 0.058    | 0.136 | −0.038 |
| Ldh   | 0.853    | 0.084    | −0.088 | 0.025 |
| Abpack | 0.835 | 0.011    | −0.069 | −0.015 | 0.014 |
| Lbarpo | 0.844 | 0.043    | −0.083 | −0.075 | −0.121 |
| Ltra | 0.997    | 0.009    | −0.012 | 0.004 | −0.002 |
| Lppro | 0.936    | 0.025    | −0.022 | 0.002 |
| Lmsk | 0.844    | 0.051    | −0.013 | −0.028 |
| Lacmi | 0.852    | 0.036    | −0.057 | 0.000 |
| Pomac | 0.900    | 0.047    | −0.030 | 0.037 |
| Lastf | 0.890    | 0.014    | 0.038 | −0.054 |
| Intchar | 0.957 | 0.009    | −0.030 | 0.001 | −0.003 |
| Trawha | −0.032 | −0.114    | 0.746 | 0.019 | 0.031 |
| Lainli | −0.012 | −0.149    | 0.358 | 0.898 | 0.030 |
| Waribee | −0.009 | −0.144    | 0.361 | 0.898 | 0.033 |
| Laskbee | −0.019 | −0.134    | 0.403 | 0.873 | 0.036 |
| Laruntrc | −0.048 | 0.071 | 0.878 | 0.032 | −0.263 |
| Flasc | −0.051    | 0.924    | 0.128 | 0.109 |
| Wropco | 0.027 | 0.671    | 0.262 | 0.092 |
| Burnst | −0.010 | −0.037    | 0.541 | 0.122 |
| Usofche | 0.028 | 0.810    | 0.144 | −0.049 |
| Laawapol | −0.045 | 0.758 | −0.156 | 0.306 |
| Larrce | 0.014    | 0.839    | 0.070 | 0.166 |
| Nonavin | −0.016 | −0.079    | 0.823 | 0.092 | 0.116 |
| Latecknw | −0.040 | 0.123 | 0.750 | −0.022 | −0.354 |
| Insudisma | −0.038 | 0.011    | 0.857 | 0.096 | −0.086 |
| Conawa | 0.004    | −0.056    | 0.885 | 0.198 | 0.113 |
| Defo | −0.003    | −0.091    | 0.658 | 0.535 | 0.108 |
| Hico | −0.036    | −0.111    | 0.121 | −0.052 | 0.843 |
| Laccre | −0.008 | 0.053 | 0.081 | 0.916 |
| Laacfi | 0.006    | −0.162    | 0.062 | 0.101 | 0.921 |
| Endis | −0.006    | −0.014    | 0.003 | −0.054 |
| Pepre | −0.008    | 0.070    | 0.135 | 0.529 |
| Spiders | −0.010 | 0.017 | −0.014 | 0.003 | −0.054 |
| Wasps | −0.004    | 0.022    | −0.014 | 0.003 | −0.054 |
| Lizards | −0.017 | −0.033 | −0.121 | −0.160 |

(Continued)
Regarding the marital status of the household head, its coefficient is positive and strongly significant, which indicates that married rural household heads were more likely to adopt beekeeping practices than their counterparts (single, divorced, and widowed; Table 7). This phenomenon was also observed in Ghana where a large proportion of the beekeepers were married (Jeil et al., 2020).

The coefficient of household size was negative and significant, which indicates that having a large household size reduces the probability of beekeeping adoption in the study area (Table 7). This may be because large household sizes require a larger proportion of their income to be spent on basic needs, which in turn restricts larger size rural households from adopting beekeeping practices. This may not be true in other countries. For example, Amulien et al. (2017) reported no significant difference in household size between beekeepers and non-beekeepers in Uganda.

The educational status of the household head (literate dummy) was positive and significant in influencing the probability of beekeeping adoption, which indicates that being a literate increases the probability of being an adopter of beekeeping (Table 7). Education helps households to easily search and know the benefits of beekeeping, and information about production and marketing of honey produce so that they can decide whether to adopt beekeeping practice or not. Educational level had a positive influence on the adoption of box hive (improved technology introduced to Ethiopia in the 1960’s), which could be because education increases knowledge, accesses to information and understanding of the technology (Adgaba et al., 2014). The result is also consistent with the finding of Tulu et al. (2020) who reported that education level is the significant determinant of adoption of improved beekeeping technology. Tareken and Ayele (2020) also reported that education level has a significant effect on technical efficiency of honey producers.

The coefficient of the number of visits by extension agents was positive and significant indicating that an increase in the frequency of visits increases the probability of beekeeping adoption by rural households (Table 7). The number of extension visits is crucial to improve the economic activities of rural households by providing necessary information on production and marketing of agricultural products including honey. This result is consistent with the findings of Tareken et al. (2017) who reported that the frequency of extension contacts determines the market outlet choice decision of honey producers. Tulu et al. (2020) also reported that visiting demonstration sites is an important factor for improving the adoption of beekeeping technology. The finding of Tareken and Ayele (2020) showed that extension contact has a significant effect on technical efficiency of honey producers. However, since the educational level of beekeepers varies, it is important that beekeeping extension, education, and training have a practical focus and is made appropriate to suit the specific needs of the recipient beekeepers (Schouten, 2021).

Membership in a farmers’ association has a positive and strongly significant influence on beekeeping adoption by rural households (Table 7). This indicates that being a member of

| PC     | 1     | 2     | 3     | 4     | 5     |
|--------|-------|-------|-------|-------|-------|
| Birds  | −0.010| 0.954 | 0.000 | −0.017| −0.081|
| Snakes | −0.003| 0.951 | −0.035| 0.008 | −0.087|
| Seaews | −0.009| 0.871 | 0.094 | −0.185| −0.011|
| Showa  | 0.001 | 0.958 | −0.013| −0.028| −0.021|
| Deaco  | −0.006| 0.920 | −0.032| −0.028| −0.032|
| Redbeco| 0.027 | 0.890 | −0.065| −0.038| −0.082|
| Shobebo| −0.061| 0.853 | −0.030| −0.043| 0.005 |

Note: Extraction method: “Principal Component Analysis”; Rotation method: “Varimax with Kaiser Normalization”
a farmers’ association increases the chance of adopting beekeeping practices. Membership in an association gives a networking opportunity to farmers to discuss and share experience with other members to reap the benefits from it and diversify their economic activities. Tarekegn et al. (2017) found that cooperative membership is one of the significant determinants of market outlet choice for honey producers. This result is also consistent with the finding of Tarekegn and Ayele (2020) who reported that cooperative membership has a significant effect on the technical efficiency of honey producers in Southern Ethiopia.

The coefficient of access to credit was positive and had a significant influence on beekeeping adoption, which indicates that household heads who had access to credit have a higher probability of being an adopter of beekeeping practices (Table 7). Access to credit can enable rural households to purchase necessary equipment for beekeeping activities and easily adopt improved beekeeping technologies. Such access can also help beekeepers to expand and grow their business, which will also improve their livelihoods. This result is consistent with that of Tulu et al. (2020) who reported that access to credit is one of the constraints of adopting improved beehive technology that can increase honey yield. The finding of Amulien et al. (2017) revealed that the intensity of beekeeping adoption (i.e., the number of beehives owned) was primarily dependent upon the beekeepers’ membership to a saving or credit group.

Among the five PCs representing constraints of beekeeping adoption, four of them negatively and significantly influence the adoption of beekeeping. The coefficient of the first principal

| Table 7. Maximum likelihood estimation results of the binary logistic regression model |
|--------------------------------|-----------------|-------------|
| **Explanatory variable**                              | **Coefficient** | **P-value** |
| Sex of the household head (Male dummy)               | 1.357           | 0.019**     |
| Age of the household head in number of years        | −0.076          | 0.955       |
| Marital status of the household head (Married dummy)| 5.362           | 0.005***    |
| Household size measured by the number of persons in the family | −0.825          | 0.012**     |
| Educational status of the household head (Literate dummy) | 2.541           | 0.015**     |
| The number of years a household lived in the district | −0.060          | 0.801       |
| Number of visits by extension agents in the previous year | 0.005           | 0.081*      |
| Membership in a farmers’ association (Member dummy)  | 3.098           | <0.001***   |
| Access to credit to the household (Yes dummy)       | 2.163           | 0.038**     |
| Whether a household processes honey produce (Yes dummy) | 0.016           | 0.752       |
| Marketing constraints (PC1)                          | −0.449          | 0.071*      |
| Natural constraints (PC2)                            | −0.120          | 0.091*      |
| Constraints for honeybee production (PC3)            | −0.662          | 0.059*      |
| Management constraints (PC4)                         | 0.075           | 0.672       |
| Financial constraints (PC5)                          | −1.177          | 0.023**     |
| Constant                                             | 3.180           | 0.135       |

Likelihood ratio $\chi^2 = 472.48$; P-value $< 0.001$

Note: ***, **, and * represent significance at the 1%, 5%, and 10% level of significance, respectively.
component (PC1), which is labelled as “marketing constraints” was negative and had a marginally significant influence on beekeeping adoption in the study area (Table 7). This indicates that all the 16 marketing-related constraints under the principal component of “marketing constraints” have a negative influence on beekeeping adoption. Rural households facing these constraints have a low probability of being an adopter of beekeeping. According to the finding of Tulu et al. (2020), marketing problem is one of the determinants of adopting improved beekeeping technology in Southwestern Ethiopia. Mushonga et al. (2019) also reported that beekeeping in Kayonza is still largely traditional that uses antiquated production methods, and that underutilizes available marketing channels.

The second principal component (PC2) labelled as “natural constraints” incorporates 12 constraints arising from natural factors that are out of the control of rural households. The coefficient of natural constraints was negative and had a marginally significant influence on beekeeping adoption indicating that having these natural constraints decreases the probability of beekeeping adoption by households (Table 7). Diseases and pests of honeybee were reported to be major constraints for the adoption of improved beekeeping technology that could minimize the reduction of honey yield (Tulu et al., 2020). According to Wakagri and Yigezu (2021), most of the constraints for honeybee production constraints were extreme temperatures, relative humidity, drought, and pests.

The negative coefficient of PC3 (constraints for honeybee production) was also marginally significant, which indicates that the 12 honeybee production constraints contribute to lower beekeeping adoption. That is, households facing these constraints are less likely to adopt beekeeping practices (Table 7). This finding is also corroborated by that of Tulu et al. (2020) who identified lack of beekeeping equipment as one of the major constraints that led to a low level of honey yield.

The coefficient of the fourth PC (management constraints) was not significant (Table 7). However, the fifth PC (financial constraints) has a negative and significant influence on beekeeping adoption by rural households (Table 7). This indicates that the four constraints collectively labelled as “financial constraints” reduce the probability of beekeeping adoption by rural households in the study area. Other studies including those by Tulu et al. (2020), Abebe (2007), and Amulen et al. (2017) also reported similar effects of financial constraints on beekeeping adoption.

3.4.6. Marginal effects of the determinants of and the constraints for beekeeping adoption

The marginal effects of the determinants of and the constraints for beekeeping adoption after the estimation of Logit regression model are shown in Table 8. As indicated in the table, other things remaining constant, being a male headed household increases the probability of beekeeping adoption by 31.8%, and married head of households have a higher chance (86.9%) of being an adopter than their counterparts, which could be because married head of households might get complementary supports from their spouse than single head of households even though responsibility in the family could be an additional burden for married household heads.

An increase in household size by one person decreases the probability of beekeeping adoption by 20.2%, other things being equal (Table 8). This could be due to the high expenditure incurred for consumption as the size of the family increases. Regarding the educational status of the household, other things remaining constant, being literate have a high probability of beekeeping adoption (56.1%) than their counterparts (Table 8). An increase in the frequency of extension visit by one increases the chance of beekeeping adoption by 0.2%, other things remaining the same (Table 8). Being a member of a farmers’ association increases the probability of beekeeping adoption by 64.7% and having access to credit increases the probability of being an adopter by 49%, other things remaining the same (Table 8).
Table 8. Marginal effects of the determinants of beekeeping adoption after logit analysis

| Explanatory variable                                              | Marginal effect | P-value |
|------------------------------------------------------------------|----------------|---------|
| Sex of the household head (Male dummy)                          | 0.318          | 0.014** |
| Age of the household head in number of years                    | -0.019         | 0.923   |
| Marital status of the household head (Married dummy)            | 0.869          | 0.003***|
| Household size                                                   | -0.202         | 0.011** |
| Educational status of a household head (Literate dummy)         | 0.561          | 0.012** |
| The number of years the household lived in the district         | -0.015         | 0.401   |
| Number of visits by extension agents                            | 0.002          | 0.062*  |
| Membership in a farmer’s association (Member dummy)             | 0.647          | <0.001***|
| Access to credit to the household (Yes dummy)                   | 0.490          | 0.046** |
| Whether a household processes honey produce (Yes dummy)         | 0.004          | 0.743   |
| Marketing constraints (PC1)                                      | -0.110         | 0.064*  |
| Natural constraints (PC2)                                        | -0.029         | 0.075*  |
| Constraints for honeybee production (PC3)                       | -0.162         | 0.057*  |
| Management constraints (PC4)                                    | 0.018          | 0.661   |
| Financial constraints (PC5)                                      | -0.288         | 0.034** |

Note: ***, **, and * represent significance at the 1%, 5%, and 10% level of significance, respectively.

Regarding the marginal effects of the PCs on beekeeping adoption, financial constraints, constraints for honeybee production, and marketing constraints were the most important determinants of beekeeping adoption followed by natural constraints (Table 8). This indicates that these constraints are the main challenges for practicing beekeeping activities in the study area.

4. Conclusions and recommendations

The maximum likelihood estimation results of the binary logistic regression model used to achieve the research objectives revealed that seven of the variables significantly influence beekeeping adoption in the study area. These variables were: (1) sex of the household head, (2) marital status of the household head, (3) household size, (4) educational status of the household head, (5) number of extension visits, (6) membership in a farmers’ association, and (7) access to credit.

Regarding the PCs (group of constraints) for beekeeping, marketing constraints, natural constraints, constraints for honeybee production, and financial constraints were the statistically significant PCs that influence beekeeping adoption in the study area. The findings have some critical policy implications for the beekeeping sector as well as for the whole economy. Ethiopia has a huge potential in the beekeeping sector, although the benefits obtained from the sector are very low. To reap the benefits from the huge potential of bee colonies in the country, the government should be able to solve the constraints faced by rural households from adopting beekeeping practices. Particularly, policies focusing on improving the financial access of rural households, increasing the frequency of visits of agricultural extension agents, and enabling farmers to share their experience and knowledge by organizing them in a group or association. Other stakeholders, including NGOs, community beekeeping groups, local processors, and packagers, and researchers can also benefit from the findings of this study. The economy of Ethiopia can benefit from the beekeeping sector if the constraints are properly solved, and if modern beekeeping techniques are disseminated.
Acknowledgements
We would like to acknowledge the Dongela district Office of Agriculture and Rural Development staff members for their tireless support during the collection of data used in the study.

Funding
The authors received no direct funding for this research.

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Data availability statement
Data used for analysis can be made available as a STATA and SPSS formatted files by the corresponding author upon a reasonable request.

Disclosure Statement
There is no any conflict of interest declared by the author.

Citation information
Cite this article as: Determinants of beekeeping adoption by smallholder rural households in Northwest Ethiopia. Adino Andaregie & Tessema Astatkie, Cogent Food & Agriculture (2021), 7: 1954817.

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