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Research article

Does cluster beekeeping improve the efficiency of honey production in participant households in southwestern Ethiopia?

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ABSTRACT

The purpose of this study is to understand the determinants of participation in cluster beekeeping and its impact on the technical efficiency of honey production in southwestern Ethiopia. To this end, cross-sectional data from a household survey conducted in 2023 from 385 sample households in 3 districts were used for the analysis. An endogenous switching regression model with a probit model was used to analyze the impact of clustering beekeepers on the technical efficacy of honey production. The results of the study showed that honey production was significantly and favorably affected by the total number of hives, type of hive, and distance to an accessible forest. As indicated by the average technical efficiency (TE) at 72 %, the actual quantity of production differed from the desired production volume. The results show that the gender of the household head, access to training, access to credit, market information, frequency of extension contacts, and age of the household head are the most important determinants of households' decision to participate in group beekeeping. In addition, the result of the endogenous switching regression (ESR) model shows that participation in group beekeeping has a positive and significant effect on honey production efficiency as measured by technical efficiency (TE). Farmers who participated in cluster beekeeping were technically less inefficient than those who did not participate. Therefore, policies and development strategies that encourage further participation in cluster beekeeping could improve the efficiency of honey production of smallholder farmers in Jimma Zone, southwestern Ethiopia.

1. Introduction

Beekeeping provides farmers with numerous significant benefits worldwide. By pollinating crops, it enhances agricultural output by raising crop yields that rely on pollinators. Worldwide, bees provide pollination services valued at USD 215 billion annually [1]. Beekeeping is a source of livelihood for millions of people [2–6]. Additionally, since forests are a significant source of food for honeybees, beekeepers could advocate for the preservation of forests [7–10]. Furthermore, farmers' access to food and nutrition is improved by the nutritional and therapeutic benefits of beekeeping products [11].

Ethiopia is a top honey producer in Africa due to its unique environment and climate [12]. Over 10 million hives are located

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throughout the nation, and about 2 million people work in the honey production [13]. Although beekeepers have a long history in Ethiopia, the industry's huge potential and attention are what drive the traditional production system, that generates the most honey in the world [14]. According to the CSA [15], traditional hives account for 96 % of all hives and 91 % of all honey produced. A lesser contribution to the nation's agricultural GDP results from this low productivity. Enhancing honey producers' technological efficiency is necessary to raise the small holder's farmer's productivity.

Since 1991, the Ethiopian government has taken various agricultural policy measures to increase agricultural production and productivity to reduce poverty and food insecurity [16]. Cluster beekeeping has recently been practiced in the context of the Agricultural Commercialization Cluster to improve productivity and income in subsistence agriculture by transforming subsistence agriculture into market-oriented agriculture [17,18].

In the context of agriculture in Ethiopia, cluster beekeeping is an agricultural production strategy in which a group of farmers on neighboring land join together to farm and take advantage of common challenges and opportunities. From a smallholder farmer's point of view, cluster beekeeping offers great benefits [19]. It is debatable if cluster beekeepers are inherently more productive than non-participants. Members of cluster beekeeping groups are anticipated to be more technically proficient because they must facilitate farmers' communication with extension service providers, supply inputs, and offer embedded support services. Cluster beekeeping is a unique and innovative approach involving clusters of beehives near each other to encourage collaboration and efficiency among the bees.

Even though various cluster beekeeping systems are growing in the country in general and in Jimma Zone in particular, the studies that have examined the impact of cluster beekeeping at the farm household level in Ethiopia [17,18,20,21], few studies analyze the honey efficiency at the cluster beekeeping level in a developing country [22] and none in Ethiopia. The degree to which cluster beekeeping contributes to honey's technical efficiency has not yet been precisely measured, despite the subsector's potential benefits overall. Even though honey production in the country has increased recently, whether this increase in productivity is a result of cluster beekeeping or not is still an important research question. Therefore, the beekeepers in the study area needed to know more and gain more knowledge about the relationship between cluster beekeeping and productivity.

In three ways, this study adds to our understanding of the profitability of cluster beekeeping. First, the impacts of cluster beekeeping participation are calculated using an endogenous switching regression model with treatment effects. A limitation of earlier research is addressed by the implementation of this model, which enables the identification of counterfactual results to determine the effects of cluster beekeeping participation after adjusting for both observed as well as unobserved household features that could correlate with beekeeping participation and the technical productivity of honey production. Second, assess how much cluster beekeeping directly contributes to the technical effectiveness of honey production, as well as the indirect benefits of pollination and returns on productive investments for agricultural inputs, for example, fertilizers. Previous research overestimated the impacts of cluster beekeepers not just because it did not account for such indirect advantages, but also because it did not control the unobserved differences in beekeeping methods. This highlights the necessity of using adequate estimation methodologies to prevent under-estimating the benefits. Thirdly, this research offers the first accurate assessment of the contribution of cluster beekeeping to the areas under investigation. To make wise decisions and boost investment in the targeted areas, local governments are increasingly requesting quantitative proof of the advantages of cluster beekeeping. These findings may help to satisfy their needs.

2. Materials and methods

2.1. Study context and survey design

This research was done in the province of Oromia Region. This study's data came from a survey of beekeepers that was carried out in southwest Ethiopia between December 2023 to January 2024. The survey covered households producing honey in 3 districts (Gera, Setema, and Sigimo) of the Jimma zone in southwestern Ethiopia. A total of 385 honey farmers were interviewed, 154 of whom belonged to a cluster of farmers. The survey sites were selected in collaboration with the District Agriculture and Rural Development Office to cover a wide range of agricultural intensities, from extensive to intensive honey production.

For collecting data from beekeepers, 385 pretested questionnaires were provided. A total of 385 pre-tested questionnaires were distributed to collect data from beekeepers. Six interviews involving key informants (KIIs) were conducted by kebele development agents (DAs) and district-level beekeeping experts. Twenty-four focus group conversations (FGDs) with experienced model beekeepers were also held to identify challenges in the production of honey, and cluster beekeeping at the rural household level. Various district and zonal agricultural office reports and databases, including both published and unpublished records, were used to gather secondary data, such as the number of beekeepers and Potential kebeles, the type and number of hives, and the beekeeping practices used in each district.

For the sampling strategy, a multi-stage stratified sampling procedure was used to select a representative sample household. In the initial stage, Gera, Setema, and Sigimo districts were chosen for their potential for honey production and improved beekeeping cluster practices. In the second phase, three kebeles were randomly chosen from each district from a list of those who had implemented cluster beekeeping throughout the previous five years. Households were separated into two strata during the third and final phase: participants (those who practiced cluster beekeeping) and non-participants (those who did not). Using kebeles and district sizes as a guide, sample households were chosen at random from each stratum. Thus, 154 households were selected from the group of participants and 231 households from the group of non-participants in cluster beekeeping. Thus, 385 households in all have been selected in this study. The Geographical locations of the sample districts and the honey production potential of each district are given in Fig. 1.

2.2. Cluster beekeeping impact on the efficiency of honey production: endogenous switching regression approach

Utilizing an effective "endogenous switching regression'' (ESR) model, we examine how cluster beekeeping affects the technical efficiency of honey. The endogenous switching regression model comprises two stages. The first stage involves estimating the selection equation for cluster beekeeping. A probit model is used to estimate this stage of the ESR design. After using this methodology in several research [23–25], this study employed a random utility model to explain a household's choice to start a cluster of bees. In order to obtain technology, agricultural inputs, extension services, collaboration, and knowledge through cooperative efforts, farmers frequently become members of cluster beekeeping organizations. We use ESR to account for both observable and unobservable endogeneity in participation decisions. This involves constructing participation functions (equation (1)) and appropriate outcome equations for each group.

$$y_1 = X_1\omega_1 + \epsilon_1 \text{ if } D = 1 \tag{1}$$

$$y_0 = X_0\omega_0 + \epsilon_0 \text{ if } D = 0 \tag{2}$$

here y_i is a vector of dependent variables representing the results for Participants (y_1) and non-participants (y_0), Xi is a matrix of explanatory variables, ω_i is a vector of parameters to be estimated and ϵ_1 and ϵ_0 are error terms. A trivariate normal distribution with zero mean vectors and the following covariance matrix is assumed for the error terms from the three equations ε, ϵ_1 and ϵ_0:

$$cov(\varepsilon, \epsilon_1, \epsilon_0) = \begin{bmatrix} \sigma^2_{\epsilon 0} & \sigma_{\epsilon 1 \epsilon 0} & \sigma_{\epsilon 0 \varepsilon} \\ \sigma_{\epsilon 1 \epsilon 0} & \sigma^2_{\epsilon 1} & \sigma_{\epsilon 1 \varepsilon} \\ \sigma_{\epsilon 0 \varepsilon} & \sigma_{\epsilon 1 \varepsilon} & \sigma^2_{\varepsilon} \end{bmatrix} \tag{3}$$

Where σ^2_{ε} is the variance of the selection equation (equation (3)), $\sigma^2_{\epsilon 0}$ and $\sigma^2_{\epsilon 1}$ are the variances of the outcome equations for non-participants and participants, while $\sigma_{\epsilon 0 \varepsilon}$ and $\sigma_{\epsilon 1 \varepsilon}$ are the covariance between ϵ_1 and ϵ_0. If ε is correlated with ϵ_1 and ϵ_0, the expected values of ϵ_1 and ϵ_0 are not equal to zero under the sample selection condition.

$$E(\epsilon_1 | D = 1) = \sigma_{\epsilon 1 \varepsilon} \frac{\phi(Z_i\omega_i)}{\Phi(Z_i\omega_i)} = \sigma_{\epsilon 1 \varepsilon}\lambda_1 \tag{4}$$

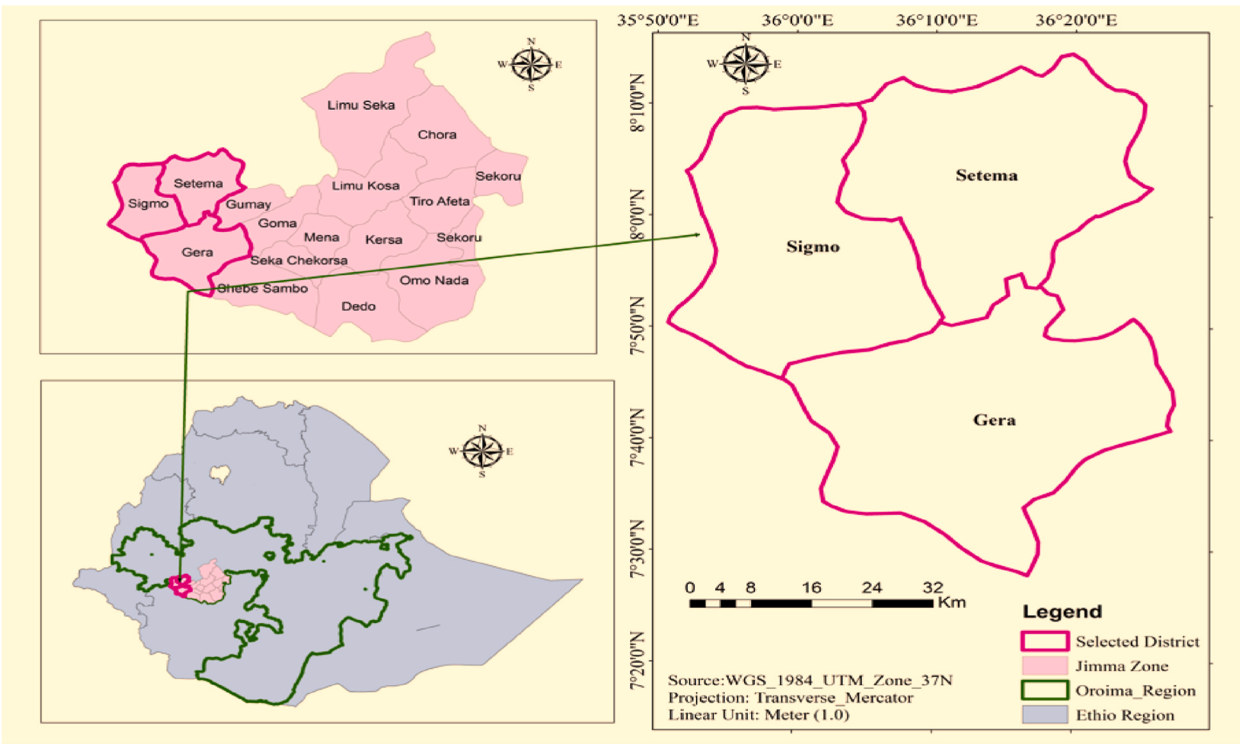

Fig. 1. Map of study area.

$$E(\epsilon_0|D=0) = \sigma_{\epsilon 0\varepsilon}\frac{-\phi(Z_i\omega_i)}{1-\Phi(Z_i\omega_i)} = \sigma_{\epsilon 0\varepsilon}\lambda_0 \quad (5)$$

where ϕ and ϕ are the probability density and the cumulative distribution function of the standard normal distribution, respectively. If $\sigma_{\epsilon 1\varepsilon}$ and $\sigma_{\epsilon 0\varepsilon}$ are statistically significant, this would indicate that the adoption decision and the outcome variable of interest are correlated, indicating a bias in the sample given under equations (4) and (5).

OLS would therefore produce skewed and inconsistent findings when used to estimate the outcome equations. An endogenous switching regression can be fitted using a full information maximum likelihood (FILM) estimation given heteroscedastic error terms. This regression simultaneously estimates the outcome and selection equations and yields consistent estimates.

The following are some uses for the ESR: comparing the actual expected outcomes of the participants (6) and those who do not participate (7), and investigating counterfactual hypothetical instances in which participants did not participate (9) and the non-participants participated (10), equations (6)–(9) are specified as follows:

$$E(y_1|D=1) = X_1\omega_1 + \sigma_{\epsilon 1\varepsilon}\lambda_1 \quad (6)$$

$$E(y_0|D=0) = X_0\omega_0 + \sigma_{\epsilon 0\varepsilon}\lambda_0 \quad (7)$$

$$E(y_0|D=1) = X_1\omega_0 + \sigma_{\epsilon 0\varepsilon}\lambda_1 \quad (8)$$

$$E(y_1|D=0) = X_0\omega_1 + \sigma_{\epsilon 1\varepsilon}\lambda_0. \quad (9)$$

Lastly, we compute the variations among equations (6) and (7) for the average effect of therapy on the treated (ATT) and the difference in the average treatment impact on the untreated (ATU) between equations (8) and (7). Additionally, we compute the effect of baseline heterogeneity for the group of Participants (BH1) as the difference between equations (6) and (8) and for the group of non-Participants (BH2) as the difference between equations (8) and (9). The empirical analysis is carried out using the STATA statistical package. The matching process is preceded by the specification of the endogenous switching regression for the treatment variable.

2.3. *Stochastic frontier model (SF)*

We used beekeeping farmers' technical efficacy (TE) as our outcome variable in order to assess how cluster beekeeping engagement affected the productivity of honey output. According to Tarekegn and Ayele [13], TE is the capacity of a choice unit to generate the most output from a specific bundle of inputs. Technical inefficiency is defined as any departure from this maximal production [26]. Both parametric and non-parametric methods can be used to quantify TE.

The technical efficacy of producers was employed as an outcome variable to analyze the influence of cluster beekeeping activity on honey production efficiency. Tarekegn and Ayele [13], define TE as a decision unit's capacity to generate the greatest output given a given package of inputs. Technical inefficiency is defined as any divergence from this maximal production. Both parametric and non-parametric methods can be used to quantify TE. The primary distinction between the two methodologies is that the non-parametric approach presumes complete control over the production process by the decision unit, and any deviation from the frontier is attributed to inefficiency. However, inefficiencies are distinguished from deviations resulting from causes other than the decision-making unit's management by the parametric approach [27].

The stochastic frontier method was employed in this investigation to estimate TE. As opposed to nonparametric data envelopment analysis, this method was chosen because it used the maximum likelihood method, which yields more reliable findings than mathematical programming-based data envelopment analysis [28]. Furthermore, the inherent variability of honey production from random shocks, and measurement mistakes are likely to affect the production data that is currently available [29].

Honey production is erratic due to these mistakes and sporadic shocks. As a result, the disturbance term's primary features—that is, its symmetric and one-sided components—led to the application of the stochastic production frontier [30]. Therefore, the stochastic frontier model independently developed by Aigner et al. [31] was adopted for this cross-sectional data. The model was thus specified given under equation (10) as follows:

$$\ln(y) = x_i\beta + v_i - \mu_i, = 1, 2, ..N, v \approx (0, \sigma 2v) \quad (10)$$

where the ith productive unit, x_i is a vector of inputs, β is the vector of technology parameters, v_i is the measurement and specification error and μ_i is the inefficiency. It is also assumed that *VI* and μi are independent of each other and independently and identically distributed over the observations [28].

There are benefits and drawbacks to both of the functional forms that are most frequently used Cobb-Douglas and Translog. The stochastic frontier and econometric estimation of inefficiency are two applications where both models are widely used in the literature [30]. In the production function, all of the honey produced by the home in the 2022–2023 production seasons is Cobb–Douglasable, nonetheless, according to the outcome of a hypothesis test conducted for this study. The production function uses the total number of hives (nbh) and the forest cover as explanatory variables. Thus, Cobb–Douglas frontier function is represented in Equation (11).

$$Ln(output) = \beta o + \beta 1\ \ln(\mathrm{lnnbh}) + \beta 2\mathrm{lnforcg} + \beta 4\ \ln(lnlabr) + \beta 5\mathrm{typbh} + vi - ui \quad (11)$$

where: Output = amount of honey produced in 2023 E C (in kilograms), β1 = number of hives, β2 = forest cover of area in hectares, β3

= labor input in person-days, β4 = type of hive, (V_i) is intended to capture the effects of stochastic noise and is assumed to be independent and identically distributed, which is expressed by N (0, σv2) (U_i) is a non-negative random variable that should take into account the technical inefficiency in production and is distributed as semi-normal, u ∼ N (0, $σu^2$)

To quantify the influence of cluster beekeepers on honey production efficiency, this study used honey producers' technical efficiency as a surrogate variable. The hypothesis tests for the parameters of the frontier model are performed using the generalized likelihood ratio statistic λ, which is defined in Equation (12) as follows:

$$1 = -2[\log L(H_o) - \log L(H_1)] \quad (12)$$

The Cobb–Douglas form is appropriate for stochastic frontier analysis, as demonstrated by the generalized likelihood ratio test. This study also rejected the null hypothesis, which held that socioeconomic characteristics could not account for the occurrence of technical inefficiency.

3. Results and discussion

3.1. The socio-economic characteristics of the respondents

Key variables used in this study include demographic and socioeconomic characteristics, inputs used in production, production value, and village-level characteristics. Of the total sample households considered, 154 beekeepers are members of beekeeping clusters and the remaining 231 are independent farmer households (i.e. the comparison group). In general, beekeepers cluster farmer households have higher levels of education, are older, are more inclined to have a male head of family, and are larger in terms of number of adults and adult equivalents. Of the 385 household heads in the sample, 285 are male and 100 are female. This means that the majority of cluster beekeeping participants were male household heads. A statistically significant correlation (significance level of 1 %) has been found between the sex of the head of the family and involvement in cluster beekeeping, according to the results of the chi-square test.

In terms of the head of the household's educational attainment, 39.99, 39.48, 18.44, and 9.09 of them are illiterate, have adult or literacy education, have completed elementary education, and have completed secondary or higher education, respectively. This demonstrates that 39.99 percent of heads of households are uneducated. Of these, about 25.32 % of cluster beekeeping participants and 38.10 % of non-cluster beekeeping participants are illiterate. Moreover, 25.32 % of cluster beekeeping participants and 38.10 % of non-cluster beekeeping participants are illiterate. Regarding education level, there is a statistical difference between participants and non-participants at the 1 % level.

Total number of participants in training is 190 (153 from cluster beekeepers and 37 from non-cluster beekeeper). The total number of beekeepers who do not participate in training is 195 (1 from cluster beekeepers and 194 from non-cluster beekeepers). Table 1 shows that, at a 1 % significant level, there exists a significant difference in cooperation beekeeping involvement between those who participate in cluster beekeeping and those who do not. Out of the total sample houses, about 56.36 % had access to formal financial institutions' credit, whereas 43.64 % did not. Out of non-cluster beekeeping participants, about 29.87 % had no access to credit, whereas 70.13 % of cluster beekeeping participants had access to credit from formal financial institutions (Table 1). The findings indicate a no significant difference in access to credit. This shows that participation in non-cluster beekeeping was constrained by access to credit compared to participation in cluster beekeeping and participation in non-cluster beekeeping of the total sample households, it can be estimated that 57.92 % of people are without access to market information, while 42.08 % of people do. On the other hand, among sampled cluster beekeeping participants, 99.35 % had access to training, while the remaining 0.65 % of them had no access to training. This indicates that cluster beekeeping participants have more access to training. According to the results of the Chi-square test, there is a statistically significant correlation of 1 % between training access and participation status in cluster

Table 1
Demographic, institutional, and resource characteristics of the respondents (dummy variables).

Variables		Total sample (N = 385)		Non-participant (231)		participant (154)		
		No	%	No	%	No	%	χ^2 test
Sex hh	Female	100	25.97	79	34.20	21	13.64	20.319***
	Male	285	74.03	152	65.80	133	86.36	
Education								7.7272***
	Illiterate	127	39.99	88	38.10	39	25.32	
	Adult/read/write	152	39.48	87	37.66	65	42.21	
	Education1	71	18.44	36	15.58	35	22.73	
	Education2	35	9.09	20	8.66	15	9.74	
Training access	No	195	50.65	194	83.98	1	0.65	256.71***
	Yes	190	49.35	37	16.02	153	99.35	
Credit access	No	168	43.64	122	52.81	46	29.87	19.776***
	Yes	217	56.36	109	47.19	108	70.13	
Market Information	No	223	57.92	215	93.07	8	5.19	292.78***
	Yes	162	42.08	16	6.93	146	94.81	

Key: ***, **, and * significant at 1 % and 5 % probability level, respectively.

beekeeping (Table 1).

Table 2 lists the average values for homes categorized as cluster beekeeping participants and non-participants. The results indicate that differentiating between cluster beekeeping participants and non-participants is statistically significant based on factors such as family size, beekeeping background, distance from the market, & frequency of extension visits. The surveying household heads were 43.71 years old on average; the average age distribution was 38.41 years for cluster beekeepers and 47.24 years for non-cluster beekeepers. The results indicate no statistically significant difference between cluster beekeeping participants and non-cluster beekeeping participants and show that cluster beekeeping participants are slightly younger than non-cluster beekeeping participants. The research area's average family size is 5.01 per home, with participants' average family sizes being 4.41 and non-participants' average family sizes being 5.41.The findings indicate that there is a statistically significant difference in family size between participants and nonparticipants. The sample as a whole has 14.503 years of average farming experience. Participants in cluster farms average 12.870 years of farming experience, compared to 15.593 years for non-participants. According to the statistical analysis, there is a statistically significant difference in the agricultural experience of the participants and non-participants.

Respondents in the sample travel an average of 15.97 km for the total sample, and 7.71and 16.72 km to the nearest market when participating in a cluster farm and not participating in a cluster farm, respectively. In terms of the distance to the closest market, the statistical analysis reveals a difference between beekeeping involvement in clusters and non-clusters. Households contact extension services on average 1.12 times per year. The mean value of the frequency of contact with extension services for participants is 1.43 years, while the mean value for non-participants is 0.92 years. Participant and non-participant interaction with counsel differed statistically significantly, according to the statistical study.

3.2. Determinants of honey production

Table 3 shows that the number of own hives, the type of hives used and Bee forage cultivation are the most important determinants of honey production. According to the regression analysis, a 1 % increase in beehive count is expected to result in a 0.421 percent ($p < 0.019$) increase in honey production, ceteris paribus. Labor did not significantly affect honey output. The direct correlation between the amount of labor employed and the total number of beehives possessed may explain the significance of labor compared to honey yield. Table 3 presents maximum likelihood estimates for the stochastic frontier model.

3.3. Honey productivity and technical efficiency among cluster beekeeping participants and non-participants

Table 4 displays the descriptive statistics and *t*-test results on the technical productivity of honey for cluster beekeepers participants and non-participants. Honey has an average technical efficiency of 0.756 for sample respondents, 0.712 for cluster farm participants, and 0.044 for non-participants. This reveals that cluster beekeeping participants have much higher honey efficiency than non-participants, having a mean difference of 0.044. The *t*-test results demonstrate a significant average disparity of one among cluster farm participants with non-participants in terms of honey technical efficiency.

3.4. Determinants of participation in cluster beekeeping

The findings of the first step of a binary probit estimate of the ESR are shown in Table 5, together with the marginal effects used to determine the factors that affect households' decisions to engage in cluster beekeeping.

The model's results show that the household head's age has a significant negative impact on cluster beekeeping participation, while the household head's sex, access to training, credits, market information, and regular extension contacts have a significant positive impact.

The age of the head of the home has a detrimental impact on the likelihood of a participation decision, as the table illustrates, even at a 1 % significance level. The negative sign indicates that a household's likelihood of engaging in cluster beekeeping decreases as the head of the household ages. The possible reason for this is that participation in cluster beekeeping is a new approach that requires intensive use of new technologies, and improved agronomic practices, and older farmers are reluctant to adopt this new approach, technologies and improved practices required for cluster beekeeping. This finding aligns with Tadessa's research [21], which found

Table 2
Institutional, resource, production, and demographic characteristics of the respondents (continuous variables).

Variables		Participant (N = 154)	Non-participant (N = 231)	Total sample (N = 385)
	Unit	Mean +SD	Mean +SD	Mean +SD
Age of household head(***)	Number	38.41 + 9.32	47.24 + 11.8	43.71 + 11.7
Educational status (**)	Year	1.81 + 0.79	1.63 + 0.72	1.70 + 0.75
Household size(***)	Number	4.41 + 2.68	5.41 + 3.18	5.01 + 3.033
Experience of household (***)	Year	12.87 + 4.23	15.59 + 4.41	14.50 + 4.541
Cash income other than beekeeping(log) (***)	ET Birr	5212 + 5663	5339 + 5073	5288.8 + 531
Market distance(***)	Km	7.71 + 6.4	16.72 + 14.47	15.97 + 14.63
Extension contact(***)	Number	1.43 + 1.04	0.92 + 0.796	1.12 + 0.934

Key: ***, **, * represent significance at 0.01 %, 0.05 % and 0.1 % respectively.

Table 3
Maximum likelihood estimates of stochastic frontier model.

Input variables	Coefficients	Std.	*p* value
_cons	4.740	0.098	0.000
Number hive (ln)	0.421	0.028	0.019
Bee forage cultivation (ln)	−0.103	0.043	0.000
Lab our use in (man-day) (ln)	0.414	0.041	0.132
Type of beehive used	0.046	0.030	0.000

Key: ***, ** and * denote significant at the 1, 5 and 10 %, respectively.

Table 4
Honey productivity and technical efficiency among Cluster beekeeping participants and non-participants.

Variables	participant (N = 154)	Non-participant (N = 231)	Total sample(N = 385)	Diff
	Mean + SD	Mean + SD	Mean + SD	
TE	0.756 + 0.122	0.712 + 0.134	0.730 + 0.131	3.271***

Key: ***significant at 1 % probability level.

Table 5
Decision to participate in cluster beekeeping: probit model.

Variables	Marginal effects (dy/dx)
Age of the household head	−0.2698+-0.0104***
Sex of the household head	1.574 + 0.04676 *
Education status	0.4698 + 0.0182
Family size	−0.1646+-0.0063
Participations in demonstration	6.334 + 0.5089 **
Cash income other than beekeeping(log)	0.7064 + 0.02745 **
Credit access	1.485 + 0.0567 *
Market distance	−0.0063+-0.0002
Market information	4.516 + 0.3598 ***
Extension contact	0.5864 + 0.0227*
Farm experience	0.2538 + 0.0098
_cons	18.511 + 2.841

Key: ***, ** and * represent significance at a level of 1 %, 5 % and 10 % respectively.

that the head of a household's age significantly and negatively affected the likelihood of joining the extension program. This finding suggests that older farmers are less likely to acquire new knowledge and improved technology.

As anticipated, at a 10 % significant level, the head of the household's gender had a favorable and significant impact on cluster beekeeping involvement (Table 5). This indicates that household heads who are men are more likely than those who are women to engage in cluster beekeeping. This is because households led by men are far more likely to embrace new agricultural initiatives and techniques since they have greater access to social networks and Information on cluster beekeeping, whereas female-headed households are overwhelmed with household management. This finding is in line with the results of previous studies by Hussen and Geleta [32], which state that male-headed households are more likely to participate in cluster production than their female counterparts.

At the 5 % significance level, having access to training had a beneficial impact on cluster beekeeping involvement. Training improves farmers' business and technical skills and therefore encourages them to participate in cluster beekeeping. Farmers consider training in the form of theoretical and practical demonstrations on the use of inputs to be particularly important. The significance of training for the participation of new technologies was also reported by Tadessa [21] who found that farmers' participation in agricultural training facilitates the adoption of new and improved honey technologies. According to the study, farmers were more inclined to engage in cluster beekeeping if they had attended training. Smallholder farmers were less than 1 % more likely to participate in cluster beekeeping based on the frequency of their extension contacts. The positive and significant effect is mainly because beekeepers who gain more knowledge about honey production during contact with the extension service, especially about modern methods of honey production. Maintaining other parameters constant, an extra day of communication within the extension service resulted in a 0.5864-kg increase in the choice to take part in cluster production. This aligns with Arage's findings [33].

The decision to engage is positively influenced by having access to credit services, and this influence is meaningful at a significance level lower than 10 %. Access to credit services for honey producers decreased the likelihood that they would choose a collection center. This could be because producers make their choice of outlet before the harvest season to repay the credit to the provider (trader) in kind or through apiculture products. In other words, farmers with credit can cover the costs of production and marketing to locate a better market.

Participation in cluster beekeeping was positively and significantly impacted by cash revenue from sources other than beekeeping, according to Table 5's results. The fact that the connection is positive suggests that the choice to engage in cluster beekeeping is influenced by one's ability to pay. The result's foundation aligns with Tarekegn and Ayele [13].

3.5. Impact of cluster beekeeping on the technical efficiency of honey producers

The results of the ESR estimates are shown in Table 6. The result of the ESR model shows that family size and cash income (other than beekeeping) affect the technical efficiency of honey producers. Variables such as market information and income other than beekeeping influence non-participation in group farming. An important question is whether farmers who farm in groups improve their technical efficiency of honey production.

According to the ESR impact data; there is a positive and statistically significant treatment effect of beekeeping cluster participation on the technical efficacy of honey. This indicates that smallholder farmers' honey production rises when they engage in cluster beekeeping techniques.

Both the average treatment effect on treated outcomes and the average treatment effect on untreated results are significant at the 1 % probability level for the technical efficiency of honey. The participants estimated a yearly technical efficiency of 0.756, and if they hadn't engaged in cluster beekeeping, that annual technical efficiency would have been 0.685. This indicates that, in the absence of cluster beekeeping, the participants' average technical efficiency would have dropped by 0.071 per year. Likewise, the non-participants were anticipated to have a technical efficiency of 0.712 each year. By contrast, the non-participant households' annual technical productivity would have been 0.729 had they opted to engage in cluster beekeeping. According to Table 7, the average technical efficiency of the non-participants would have grown by 0.017 each year if they had taken part.

Overall, this study's results demonstrate that smallholder farmers' honey production rises when they engage in cluster beekeeping. One possible explanation for this is that smallholder beekeepers who participate in cluster beekeeping work together to achieve economies of scale through similar production methods and better prices for contemporary technology and related incentives through extension packages. This results in faster distribution of extension services among farmers and proper input management, all of which boost productivity. Our results also align with the expanding body of research on communal farming in underdeveloped nations, where the majority of researchers have discovered a favorable relationship between productivity and membership [13,17,21].

4. Conclusions and recommendations

The study examined the factors influencing smallholder farmers' decision to join cluster beekeeping and how it affects honey production efficiency in southern Ethiopia. In 2023, the study collected cross-sectional data at the farm household level. Taking into consideration both observed and unobserved heterogeneities, the ESR model was applied to assess the influence of cluster beekeepers on adoption decisions and outcomes. In general, the study's outcomes support the notion that cluster beekeeping can potentially increase farmers' productivity by creating the conditions and necessary social networks for collaboration and cooperation as well as access to technology, knowledge, and inputs. Therefore, it's critical to establish the infrastructure required and raise awareness through field trips, experience sharing, training, bolstering basic education, and supporting cooperatives to reinforce the already-existing clusters, broaden the experience, and inspire farmers to participate.

The following important conclusions are made in light of our findings. Cluster beekeeping leads to increased honey production efficiency in participating families, as evidenced by a substantial positive correlation. In particular, our ESR results show that beekeeping in clusters raises the technical efficiency of honey by 75.6 % annually. We draw our conclusion that cluster beekeeping, especially in poor nations, may be a useful policy choice for alleviating beekeepers' burdens based on the effects of cluster on various beekeeping-related factors. Relevant policy implications can be drawn from the study's findings. First, policymakers should step up their efforts to persuade beekeepers to engage in cluster beekeeping in light of the noteworthy contribution that cluster beekeeping has made to increase the productivity of honey production. This is reinforced by the counterfactual conclusion that if non-cluster beekeepers in Ethiopia participate in cluster beekeeping, their honey production potential increases. The results encourage cluster growth because, although these clusters are yet in their early stages, they certainly have a chance to boost honey production efficiency. Building stronger rural and community institutions like banking services, market access, and extension assistance is necessary to support or grow these clusters Beekeepers will also benefit from a strengthened extension and outreach infrastructure, as it will reduce information asymmetry about the existence and functioning of cluster beekeeping. Our results suggest that the benefits of the technical efficiency of honey reported in numerous studies can be continued through cluster beekeeping.

Availability of data

Information will be provided upon request.

CRediT authorship contribution statement

Kumala Deksisa: Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **Adeba Gemechu:** Methodology, Conceptualization. **Teferi Tolera:** Writing – review & editing, Methodology, Conceptualization.

Table 6
Maximum likelihood estimates with complete information for the endogenous switching regression model.

Dependent	Selection	Cluster beekeeping	
		Participation	Non participation
Age of the household head	−0.1443 + 0.050[a]	−0.0037 + 0.0046	−0.0003 + 0.0024
Sex of the household head	0.8768 + 0.4477[a]	−0.0686 + 0.0522	0.0136 + 0.0299
Education status	0.2815 + 0.2182	−0.0042 + 0.0202	−0.0172 + 0.0133
Family size	−0.126 + 0.0689[c]	−0.0172 + 0.007[b]	−0.0053 + 0.0039
Participations in demonstration	3.7883 + 1.0109[a]	−0.0695 + 0.2408	0.0141 + 0.0407
Cash income other than beekeeping(log)	0.3577 + 0.2112[c]	0.070 + 0.026[a]	0.1315 + 0.0144[a]
Credit access	0.6131 + 0.4205	−0.0307 + 0.0413	−0.015 + 0.0285
Market distance	−0.0017 + 0.0097	0.0009 + 0.0010	−0.0005 + 0.0008
Lagged price(log)	−2.868 + 3.6340	0.0306 + 0.150	0.2822 + 0.1930
Market information	−2.868 + 0.4681[a]	−0.0382 + 0.0981	−0.1228 + 0.0639[b]
Extension contact	3.634 + 0.1807[b]	−0.0014 + 0.0174	−0.0077 + 0.0160
Farm experience	0.1293 + 0.1045	0.0085 + 0.0113	0.0024 + 0.0064
_cons	10.88 + 20.22	−0.0164 + 0.9388	−2.305 + 1.112

Key: ***, **, *) represent significance at a level of 1 %, 5 % and 10 % respectively.

Table 7
The average effect of treatment on the treated (ATT) for technical efficiency (regression model with endogenous change).

Subsamples Effects	Decision Stage		Treatment effect
	To participant	Not to participant	
Cluster beekeeping	(a) 0.756	(c) 0.685	$ATT_y = 0.071$***
Non- cluster beekeeping	(d) 0.729	(b) 0.712	$ATU_y = 0.017$***
Heterogeneity effects	$BH_{1y} = 0.027$	BH_{2y} −0.027	$TH_y = 0.054$

Key: ***, **, * represent significance at 1 %, 5 % and 10 % levels respectively.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

[1] K.M. Smith, E.H. Loh, M.K. Rostal, C.M. Zambrana-Torrelio, L. Mendiola, P. Daszak, Pathogens, pests, and economics: drivers of honey bee colony declines and losses, EcoHealth 10 (2013) 434–445.
[2] R. Hecklé, P. Smith, J.I. Macdiarmid, E. Campbell, P. Abbott, "Beekeeping Adoption: A Case Study of Three Smallholder Farming Communities in Baringo County, Kenya,", 2018.
[3] J. Hinton, C. Schouten, A. Austin, D. Lloyd, An overview of rural development and small-scale beekeeping in Fiji, Bee World 97 (2020) 39–44.
[4] J. Lowore, Understanding the livelihood implications of reliable honey trade in the Miombo Woodlands in Zambia, Frontiers in Forests and Global Change 3 (2020) 28.
[5] N.S. Ribeiro, L.K. Snook, I.C.N. de Carvalho Vaz, T. Alves, Gathering honey from wild and traditional hives in the Miombo woodlands of the Niassa National Reserve, Mozambique: what are the impacts on tree populations? Global Ecology and Conservation 17 (2019) e00552.
[6] C.N. Schouten, Factors influencing beekeepers income, productivity and welfare in developing countries: a scoping review, J. Apicult. Res. 60 (2020) 204–219.
[7] T. Kassa Degu, G. Regasa Megerssa, Role of beekeeping in the community forest conservation: evidence from Ethiopia, Bee World 97 (2020) 98–104.
[8] J. Girma, C. Gardebroek, The impact of contracts on organic honey producers' incomes in southwestern Ethiopia, For. Pol. Econ. 50 (2015) 259–268.
[9] K. Ricketts, C. Shackleton, Integrating livelihoods and forest conservation through beekeeping in northern KwaZulu-Natal, Dev. South Afr. 37 (2020) 661–677.
[10] H. Meilby, P. Cross, Sticky business-Why do beekeepers keep bees and what makes them successful in Tanzania? J. Rural Stud. 66 (2019) 52–66.
[11] H. Teklewold, M. Kassie, Z. Abro, K. Mulungu, S. Sevgan, "The Role of Pollination Services and Disrupting Cropping Patterns in Closing Nutrition Gap in Sub-saharan Africa,", 2021.
[12] FAOSTAT, FAOSTAT Database, 2022. Rome, Italy, retrieved July 2022 from, www.faostat.org.
[13] K. Tarekegn, A. Ayele, Impact of improved beehives technology adoption on honey production efficiency: empirical evidence from Southern Ethiopia, Agric. Food Secur. 9 (2020) 1–13.
[14] M. Bayissa, L. Lauwers, F. Mitiku, D.C. de Graaf, W. Verbeke, System mapping of the production and value chain to explore beekeeping potential in southwest Ethiopia, Insects 15 (2024) 106.
[15] C. C. S. Agency, Key Findings of the 2013/2014 (2006 E.C.).Agricultural Sample Surveys: Country Summary, The Federal Democratic Republic of Ethiopia Central Statistical Agency (CSA), Addis Ababa, Ethiopia, 2014.
[16] S. Degefu Tadessa, IMPACT OF CLUSTER FARMING ON SMALLHOLDER WHEAT FARMERS PRODUCTIVITY: THE CASE OF LEMU-BILBILO AND HETOSA DISTRICTS OF ARSI ZONE, ETHIOPIA, Haramaya University, 2023.
[17] S. Abate, B. Kassa, "Impact of Cluster Farming on Farmer's Productivity and Commercialization: the Case of Dera Woreda," MA Thesis, 2021.
[18] M.P. Jr Tabe-Ojong, G.G. Dureti, Are agro-clusters pro-poor? Evidence from Ethiopia, J. Agric. Econ. 74 (2023) 100–115.
[19] ATA, "Ethiopian agricultural transformation agency. 2021. 2020-21(2013 E.C) annual report. www.ata.gov.et/, 2021.

[20] G.N. Tefera, M.K. Aredo, Z.S. Nejo, K.J. Ibrahim, Impact of wheat cluster farming practice on smallholder's asset building in arsi zone of Ethiopia, Journal of Business and Economic Development 8 (2023) 1–11.
[21] s. Tadessa, Impact of Cluster Farming on Smallholder Wheat Farmers Productivity: the Case of Lemu-Bilbilo and Hetosa Districts of Arsi Zone, Ethiopia, Haramaya University, 2023.
[22] Ö. Teoman, O. Yeni, Evaluation of the cluster components for apiculture products and honey in the black sea region of Turkey, Eskişehir Osmangazi Üniversitesi İktisadi ve İdari Bilimler Dergisi 16 (2021) 34–54.
[23] S. Asfaw, B. Shiferaw, F. Simtowe, L. Lipper, Impact of modern agricultural technologies on smallholder welfare: evidence from Tanzania and Ethiopia, Food Pol. 37 (2012) 283–295.
[24] A. Abdul-Rahaman, A. Abdulai, Do farmer groups impact on farm yield and efficiency of smallholder farmers? Evidence from rice farmers in northern Ghana, Food Pol. 81 (2018) 95–105.
[25] M. Khonje, J. Manda, A.D. Alene, M. Kassie, Analysis of adoption and impacts of improved maize varieties in eastern Zambia, World Dev. 66 (2015) 695–706.
[26] K. R. Paltasingh Saroj, P.K. Jena, Does Contract Farming Enhance Farm Efficiency? A Case of Wheat Growers of Haryana, 2023. India.
[27] M.H. Ahmed, K.A. Melesse, Impact of off-farm activities on technical efficiency: evidence from maize producers of eastern Ethiopia, Agricultural and Food Economics 6 (2018) 1–15.
[28] S.C. Kumbhakar, R. Amundsveen, H.M. Kvile, G. Lien, Scale economies, technical change and efficiency in Norwegian electricity distribution, 1998–2010, J. Prod. Anal. 43 (2015) 295–305.
[29] K. Shiferaw, B. Gebremedhin, Technical Efficiency of Small-Scale Honey Producers in Ethiopia: A Stochastic Frontier Analysis: International Livestock Research Institute, 2016.
[30] T.J. Coelli, D. Prasada Rao, C.J. O'Donnell, G.E. Battese, Additional topics on stochastic frontier analysis. An Introduction to Efficiency and Productivity Analysis, 2005, pp. 263–288.
[31] D. Aigner, C.K. Lovell, P. Schmidt, Formulation and estimation of stochastic frontier production function models, J. Econom. 6 (1977) 21–37.
[32] C.H. Hussen, F.T. Geleta, Factors affecting smallholder farmers participations in cluster crop production: evidence from selected districts of west shewa zone, Oromia national regional state, Ethiopia, Sarhad J. Agric. 37 (2021).
[33] A. Arage, Honey Value Chain Analysis in Gera District, Jimma Zone of Oromia National Regional State, Ethiopia, Haramaya university, 2018.