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Impact of Modern Beehive Technology Adoption on Household Income: Evidence from North Shewa Zone, Oromia National Regional State, Ethiopia

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A R T I C L E I N F O

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A B S T R A C T

Hidabu Abote, Dera, Wera Jarso and Debra Libanos districts of North Shewa zone are potential in honey production. To enhance this potential, different organizations disseminate improved beehives technologies for the smallholder farmers. However, the impact of the disseminated technologies on household income has not been evaluated. Thus, this study aimed to evaluate the impact of improved beehive adoption on household income. Purposive and two stage sampling technique was used to select 384 sampled households. The study used logistic regression model to identify the determinants of adoption decision of modern beehive technology while propensity score matching to evaluate the impact of modern beehive technology adoption on household income. The result of logistic regression model shows that age of household head, family size, households experience in beekeeping, frequency of extension contact, access to credit services, access to training and access to beehive demonstration site visit had positive and significant effect on household adoption decision of modern beehive technology. The result of propensity score matching indicates that the adopters of improved beehive technology were earned Birr 2690.383 than non-adopter. The difference in household income between the two groups shows that there is considerable room for improvement of household income through increasing the number of adopter of improved beehives technology in the study area. This should be done through provision of training, credit, extension and expansion of beehive demonstration site among the others.

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Introduction

Agriculture is a basis for the entire socioeconomic structure of the country and has a major influence on all other economic sectors and development processes and hence, plays a crucial role in poverty reduction in Ethiopia (CSA, 2021). Even if the share of agriculture to GDP is reduced recently, it has still largest contributions i'e 35% to the total country GDP, 73% to employment and 90% to foreign exchange earnings (CSA, 2021). Moreover, the livelihood of about 90% of the poor is fully or partly dependent on agriculture as a result of which, agricultural development will continue to be the basis for economic growth and development.

Ethiopia has huge potential of the apiculture sub-sector, which holds a key position for poverty reduction and natural resource conservation in the country (MoA and ILRI, 2013). Despite of its contribution for smallholder households' income in particular and nation's economy in general, honey production system is very traditional which results in low productivity and poor quality. Thus, the government of Ethiopia has amplified its attention to develop the apiculture sub-sector as one of its strategies for poverty reduction and different NGOs have been intervening to assist the poor smallholder farmers through introduction and promotion of improved beehives technologies to obtain higher production and good quality that can enable the smallholder farmers to be benefited from the sub-sector. To increase the production and productivity of honey and bee wax, different improved technologies have been used in the last 7-10 years in the country (MoA, 2015).

Oromia National Regional State government of Ethiopia under its agricultural led development policy gave due attention to apiculture development in selected areas of the region based on their prioritized potential. To develop this potential and increase production from the sector, different improved beehive technologies have been introduced. Even though large number of modern beehive technologies have been introduced and promoted by the regional bureau and other non-governmental organizations over the past 10 years, however, the amounts of modern beehive technologies used by farmers were very limited (Akinwumi et al., 2001).

In the study area (North Shewa zone) livestock and fishery department disseminated various modern beehive technologies solely and in collaboration with different projects. However, there is no compiled and tangible information regarding the impact of modern beehive technology adoption on household income in the study area. Therefore, this study aimed to evaluate the impact of modern beehive technology adoption on household income in the study area.

Research Methodology

Sampling Techniques and Sample Size Determination

The target populations of this study were honey producer households in the study area. Purposive and two stage stratified random sampling techniques were employed to select sample respondents. Among 13 districts found in North Shewa zone, 4 districts namely Hidabu Abote, Dera, Debra Libanos and Wera Jarso were purposively selected based on honey production potential. After that, a total of 8 kebeles were purposively selected based on honey production potential. Total household head in the sample kebeles were stratified into two groups (adopters & non-adopters of modern beehive technology). Finally, 192 adopters and 192 non-adopters households were randomly selected for interview. The sample size was determined using the Cochran (1977) formula specified in equation 1.

$$n = \frac{Z^2 P(1-P)}{D^2} = 384 \quad (1)$$

Where:

n = sample size;
Z = the table value of 95% confidence interval=1.96
P = the population proportion (assumed to be 0.5 for it provides the maximum sample size)
D = degree of accuracy expressed as a proportion (0.05)

Types of Data and Method of Data Collections

Both primary and secondary data were used. Primary data was collected using structure questionnaires. Key informant interview was conducted to supplement primary data. Besides, secondary data was collected from zone and district livestock and fishery office.

Method of Data Analysis

The study was used descriptive statistics, inferential statistics, and econometrics model to analyze the collected data.

Descriptive and inferential analysis

Descriptive statistics like mean, standard deviation, and percentage were used for describing the socioeconomic and institutional characteristics of sample households in the study area. Chi-square test and independent sample t-test were employed to compare the adopters and non-adopters households in terms of the hypothesized covariates.

Econometric Analysis

The two commonly used discrete choice models in the adoption studies are the probit and logit models. The results from the two models are very similar since the normal and logistic distributions from which the models are derived are very similar except for the fact that the logistic distribution has slightly fatter tails (Gujarati and Porter, 2009). The dependent variable which is normally used with these models is dichotomous in nature, taking the values 1 or 0, a qualitative variable which is incorporated into the regression model as dummy variable. This study was used binary logistic regression model to identify the factors affecting modern beehive technology adoption in the study area.

In most studies propensity score matching (PSM) method has been used to evaluate public policies or projects or programs. A PSM matches each technology adopter households with a non-adopter household that has almost the same likelihood of adopting any social programs to find the closest comparison group from a sample of non-adopters to the sample of modern beehive technology adopters. In impact estimation PSM constructs a counterfactual comparison group based on a model of the probability of participating in the treatment, using observed characteristics. Participants are then matched on the basis of this probability, or propensity score, to non-participants for the impact evaluation. Therefore, this study was used PSM model to evaluate the impact of modern beehive technology adoption on household income in the study area.

Common Support Region

The assumption is that P(x) (probabilities) lies between 0 and 1. This restriction implies that the test of the balancing property is performed only on the observations whose propensity score belongs to the common support region of the propensity score of treated and control groups (Becker and Ichino, 2002). Individuals that fall outside the common support region would be excluded in the treatment effect estimation. This is an important condition to guarantee improving the quality of the matching used to estimate the ATT (average treatment on treated). The ATT is simply the mean difference in outcomes over the common support, appropriately weighted by the propensity score distribution of participants.

Matching Quality Test

It helps to check if the matching procedure is able to balance the distribution of the relevant variables in both control and treatment group. The following common criteria were used to assess the matching qualities.

Standardized Bias: One suitable indicator to assess the distance in marginal distributions of the variables is the standardized bias (SB). For each covariate *X* it is defined as the difference of sample means in the treated and matched control subsamples as a percentage of the square root of the average of sample variances in both groups.

T-test: It is used to check if there are significant differences in covariate means for both groups (Rosenbaum and Rubin, 1983). Before matching differences are expected, but after matching the covariates should be balanced in both groups and hence no significant differences should be found.

Pseudo R^2: Sianesi (2004) suggests re-estimating the propensity score on the matched sample that is only on participants and matched non-participants and compare the pseudo-R^2's before and after matching. After matching there should be no systematic differences in the distribution of covariates between both groups and therefore, the pseudo-R^2 should be fairly low.

Definition of Variables and Hypothesis

Treatment variable: It is a dummy variable which takes value of 1 if the household adopted modern beehive technology and 0 otherwise.

Outcome variable: It is a continuous variable and defined as the amount of income household obtained from honey production in Ethiopian Birr.

Explanatory variables: The following explanatory variables were hypothesized to affect the adoption of modern beehive technology in the study area.

Results and Discussions

Characteristics of sample households in terms of categorical variables

Chi-square test was used to measure the relationship between adopter and non-adopter household in terms of the categorical variables. The result show that there was a statistically significant association between adopter and non-adopter households in terms of sex of household head, access to credit services, access to training, access to beehive demonstration site visit and types of farmer. It implies that male headed households, households who obtained credit, training, households who participated in beehive demonstration site visit and model farmers were more adopter of the improved beehive technology than non-adopter households at 1, 5 and 10% significance level (Table 2).

Characteristics of sample households in terms of continuous variables

A t-test was used to measure the mean difference of continuous variable between adopter and non-adopter households in the study area. The result show that there was statistically significant mean difference between adopters and non-adopters households in terms age of household head, family size, frequency of extension contact, beekeeping experience, and education level at 1% significance level (Table 3). This implies that older farmer; households who had large family members; large number of extension contact; more experienced farmers in beekeeping and more educated farmers were more adopter of improved beehive technology than non-adopter farmers.

Table 1. Summary of variables and hypothesis

Dependent variables	Types of variable	Measurement	Expected effect
Treatment variable Adoption of modern beehive technology adoption	Dummy	1 if adopter, 0 if not	
Outcome variable Total annual income household obtained from honey production	Continuous	Ethiopian Birr	
Explanatory variables			
1. Age of household head	Continuous	Years	+
2. Sex of household head	Dummy	1-Male; 0-Female	+
3. Educational level	Continuous	Years of schooling	+
4. Access to credit	Dummy	1-Used credit; 0-If not used	+
5. Extension contact	Continuous	Number of contact per year	+
6. Livestock size	Continuous	TLU	+
7. Family size	Continuous	ME	+
8. Experience in beekeeping	Continuous	Years	+
9. Types of farmer	Dummy	1 if model, otherwise (0)	+
10. Access to training	Dummy	1 if yes, otherwise (0)	+
11. Access to demonstration visit	Dummy	1 if yes, otherwise (0)	+
12. Access to market for honey	Dummy	1 if yes, otherwise (0)	+
13. Access to market information	Dummy	1 if yes, otherwise (0)	+

Table 2. Results of inferential analysis (chi-square test for categorical variables)

Variables		Adopters (n=192)		Non-adopters (n=192)		Total (n=384)		Pearson chi-square	
		Freq.	%	Freq.	%			X^2	P
Sex	Male	166	86.5	150	78.1	4.575	0.032**	4.575	0.032**
	Female	26	13.5	42	21.9				
Credit	Yes	126	65.6	59	30.7	46.823	0.000***	46.823	0.000***
	No	66	34.4	133	69.3				
Information	Yes	110	57.3	97	50.5	1.771	0.183	1.771	0.183
	No	82	42.7	95	49.5				
Training	Yes	126	65.6	50	26.0	60.587	0.000***	60.587	0.000***
	No	66	34.4	142	74.0				
Demonstration	Yes	116	60.4	59	30.7	34.111	0.000***	34.111	0.000***
	No	76	39.6	133	69.3				
Market	Yes	159	82.8	155	80.7	0.279	0.597	0.279	0.597
	No	33	17.2	37	19.3				
Type of Farmer	Model	23	12.0	12	6.3	3.804	0.051*	3.804	0.051*
	Ordinary	169	88.0	180	93.8				

***, ** and * denote significance at the 1, 5 and 10%, respectively; Source: Survey result (2022)

Table 3. Results of inferential analysis (t- test for continuous variables)

Variables	Adopters (n=192)		Non-adopters (n=192)		Independent sample t-test	
	Mean	Std. Err.	Mean	Std. Err.	t-value	P value
Age	46.71	0.43	37.44	0.44	-14.9	0.000***
Family size	7.55	0.08	4.60	0.10	-24.2	0.000***
Livestock size	5.69	0.16	5.87	0.17	0.50	0.747
Extension contact	8.02	0.18	3.70	0.11	-20.9	0.000***
Beekeeping experience	8.05	0.12	4.76	0.09	-21.9	0.000***
Education level	0.62	0.07	0.15	0.03	-2.60	0.000***

*** denote significance at the 1%; Source: Survey result (2022)

Table 4. Honey production among adopter and non-adopter households

Variable	Modern hive (n=192)		Traditional hive (n=192)		t-test	
	Mean	Std. Err.	Mean	Std. Err.	t-value	P value
Honey production	18.02	1.78	7.33	1.17	69.61	0.000***

Source: Survey result (2023); *** denote significance at the 1%

Honey Production Status among Adopter and Non-adopter Households'

The amount of honey produced per hive per kilogram using traditional and modern beehive was compared using independent sample t-test. The result in Table 4 shows that there was statistically significant mean difference in the amount of honey produced from traditional and modern hive at 1% significance level.

Determinants of Modern Beehive Technology Adoption in the Study Area

To identify factors affecting modern beehive technology adoption, binary logistic regression was employed. The logistic regression output stated in Table 4 revealed that age of household head, family size, households experience in beekeeping, frequency of extension contact, access to credit services, access to training and access to beehive demonstration site visit were significantly and positively influenced the adoption of modern beehive technology in the study area. The details of each explanatory variable are discussed as follow:

Age of household head: As expected, age of household head had positive and significant effect on household's modern beehive technology adoption at 10% significance level. The result indicated that as the age of household head increase by one year, the odd ratio of being adopter of the modern beehive technology would increase by 1.07 units. This is because older farmers are assumed to have gained knowledge and skill over time and hence, would able to evaluate technology than younger farmers. This result is supported by the finding of (Mignouna et al., 2011; Kariyasa and Dewi, 2011).

Family size: As expected, this variable influenced household adoption of modern beehive technology positively and significantly at p<1%. The result revealed that, other things remains constant, the odds ratio of being adopter of the technology was about 2.31 times greater for households with large family size than household with low family size. This is due to the fact that farmers with large family size might adopt the technology to satisfy the need of their family. This result is consistent with the findings of (Musa et al., 2016 and Sisay et al., 2013).

Farmers experience beekeeping: Household's experience in beekeeping had positive and significant effect on the adoption of modern beehive technology at 10% significance level. The result indicate that as household experience in beekeeping increase by one year, the odd ratio of being adopter of the modern beehive technology would increase by 1.34 units. This is due to the fact that experience would improve farmers' skill and awareness on honey production. Previous studies by Chilot et al. *(*1996); Abadi et al. *(*1999) also confirmed that experience of the household heads in beehive would positively affect adoption of modern technology.

Frequency of extension contact: This variable influenced household adoption of modern beehive technology positively and significantly at p<1%. This revealed, other things remains constant, the odds ratio of being adopter of the technology was about 2.04 times greater for households with access to extension services than households without such services. This is due to the fact that farmers who had access to extension services would be more progressive in adoption of improved beehive technology. This result is consistent with empirical findings of (Kassa et al., 2018).

Access to credit: This variable influence household adoption of modern beehive technology positively and significantly at p<5%. The result revealed that, other things remains constant, the odds ratio of being adopter of the technology was about 3.83 times greater for households with access to extension services than households without such services. This is because farmers who had access to credit would be able to buy modern beehive equipment than the others. This result is consistent with the finding of (Sisay et al., 2013; Workneh, 2017).

Access to training: This variable influenced household adoption of modern beehive technology positively and significantly at p<5%. The result revealed that, other things remains constant, the odds ratio of being adopter of the technology was about 3.37 times greater for households with access to training than households without training. This is due to the fact that training might have inculcated technical competency, more exposure to the subject matter and convinced to adopt the improved technologies in the farms. This result is consistent with empirical findings of (Rahman, 2007).

Access to beehive demonstration site visit: As expected, demonstration site visit had positive and significant effect on household's modern beehive technology adoption at 5% significance level. The result indicated that as household access to demonstration site visit increase by one unit, the odd ratio of being adopter of the modern beehive technology would increase by 3.80 units. This is due to the fact that visiting apiary sites of other beekeepers or demonstration site help the farmers to develop his/her insight in beekeeping and positive perception towards an innovation or a new technology. Study by Tamrat (2015) also confirmed that farmers' participation in field days and demonstration enhance adoption of farm technology.

Results of Propensity Scores Matching

The propensity score for a given household was estimated using logit model where the dependent variable is adoption status and taking different covariates as independent variables. The estimated propensity scores lies between 0.1381 and 0.9189 with mean value of 0.6127 for adopter households while 0.1381 and 0.8632 with mean value of 0.3873 for non-adopter households (Table 6).

Table 5. Binary logistic regression model output

Adoption status	Odds Ratio	Std. Err.	Z	P>Z
Sex	0.696209	.6024738	-0.42	0.676
Age	1.073555	.0441426	1.73	0.084*
Family size	2.310692	.4970559	3.89	0.000***
Experience	1.341721	.215385	1.83	0.067*
Education level	1.305688	.5839794	0.60	0.551
Livestock size	0.8358022	.0983069	-1.52	0.127
Extension contact	2.040419	.3673729	3.96	0.000***
Access to credit	3.834241	2.314219	2.23	0.026**
Access to information	0.6913105	.398726	-0.64	0.522
Access to training	3.371929	2.011492	2.04	0.042**
Demonstration	3.800892	2.292785	2.21	0.027**
Access to market	1.368178	.9738025	0.44	0.660
Types of farmer	2.507421	3.253501	0.71	0.479
Constant	3.17e-07	7.69e-07	-6.16	0.000
Logistic regression	Number of obs.	= 384		
	LR chi2 (13)	= 426.72		
	Prob > chi2	= 0.0000		
Log likelihood = -52.808528	Pseudo R2	= 0.8016		

***, ** and * denote significance at the 1, 5 and 10%, respectively; Source: Survey result (2022)

Table 6. The distribution of propensity scores

Descriptions	N	Mean	Std. Dev.	Min	Max
Adopter	192	0.6127	0.2348	0.1381	0.9189
Non-adopter	192	0.3873	0.1838	0 .1381	0.8632
Total sample households	384	0.5000	0.2389	0 .1381	0.9189

Source: Survey result (2022)

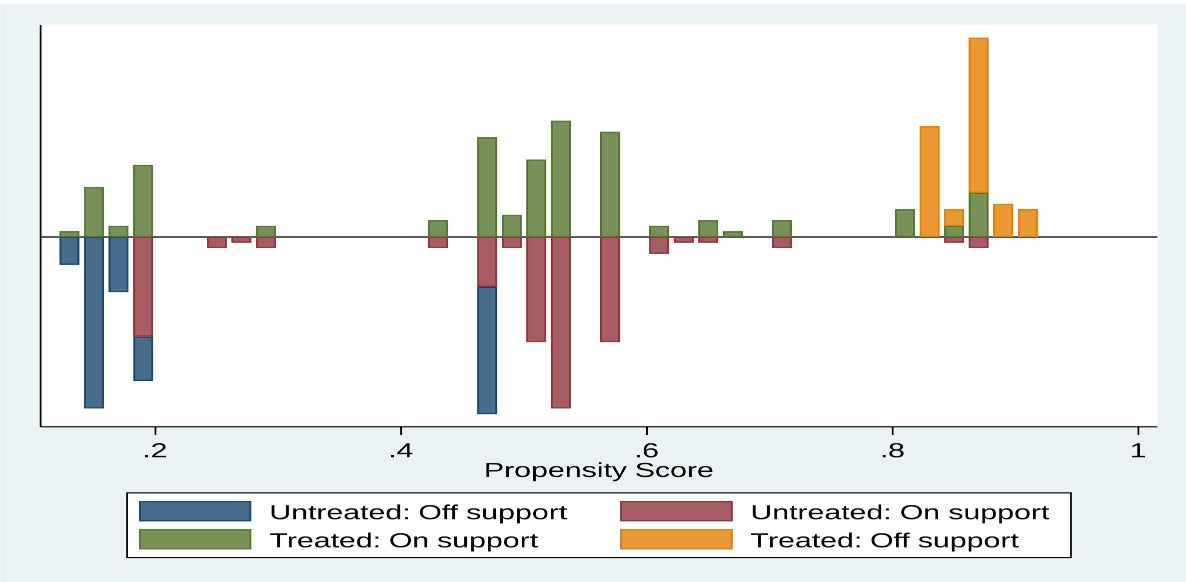

Figure 1. The distribution of propensity scores for treated and untreated groups
Source: Survey result (2022)

Table 7. Matching Quality Test

Covariates	Mean		% Bias	t-test	
	Treated	Control		t	p>t
Access to credit	.49231	.54206	-10.6	-0.76	0.448
Access to information	.56923	.69159	-19.5	-1.94	0.530
Demonstration visit	.41538	.33645	16.6	1.24	0.214
Access to market	.77692	.79439	-4.5	-0.32	0.746
Types of farmer	.09231	.09346	-0.4	-0.03	0.976
Ps R^2	LR Chi^2	$P>Chi^2$	Mean Bias		Med Bias
0.018	6.01	0.422	9.5		7.6

Source: Survey result (2022)

Table 8. The average treatment effect of matched adopter and non-adopter households

Outcome variable	Treated	Control	Difference	t-value	P-value
ATT	4544.2307	1853.8461	2690.3846	59.55	0.000***

Source: Survey result (2022); ***stands for statistical significance at 1%

Table 9. Sensitivity Analysis

Gamma	$e^{\gamma=1}$	$e^{\gamma=1.25}$	$e^{\gamma=1.5}$	$e^{\gamma=1.75}$	$e^{\gamma=2}$	$e^{\gamma=2.5}$	$e^{\gamma=2.75}$	$e^{\gamma=3}$
Sig+	0.00032	0.00058	0.0011	0.0025	0.0034	0.0062	0.0076	0.0084

Source: Model result (2022)

Common Support Region

As suggested by Bernard et al (2007) in order to ensure maximum comparability of the adopter and non-adopter households, the sample used for matching is restricted on those households who are located in the common support region. The common support region is where the values of propensity scores of both adopter and non-adopter groups can be found. The basic criterion of this approach is to delete all observations whose propensity score is smaller than the minimum of treated group and larger than the maximum of control group (Caliendo and Kopeinig, 2008). Based on the minima and maxima criterion, the region of common support is [0.1381, 0.8632] implying that the two groups share the same characteristics in these interval. Based on this criterion, 139 observations (77 from control and 62 from treatment groups) were discarded from the analysis (Figure 1).

Matching Quality Test

The pseudo R^2, t-test and standard bias are the basic tool for testing the quality of matching between treated (adopter) and control group (non-adopter). Low pseudo R^2, insignificant t-test after matching and standard bias below 20% is the universally accepted criteria to judge the quality of matching between adopter and non-adopter group (Rosenbaum and Rubin, 1983). As the result depicted in Table 7 shows that the pseudo R2 (0.018) was low, t-test value was insignificant and standard bias is below 20% (9.5%) for the selected covariates. This implies that the quality of matching was good to balance the characteristics in the treated and matched comparison group.

Results of Average Treatment Effect

The average treatment effect on treated (ATT) measures the average difference of income between the matched adopter and non-adopter households. The result of this study shows that the mean difference in total annual income between adopter and non-adopter households between the two groups of sample households is significant at 1% significance level. The average income gain due to adoption of the modern beehive technology adoption was Birr 2690.383 implying adopter households on average gain Birr 2690.383 more as compared to non-adopter (Table 8).

Results of Sensitivity Analysis

In order to overcome the unobserved bias, a Rosenbaum bounds calculation was used (sensitivity test) for the outcome effect on modern beehive technology adoption which is positive and significantly different from zero. A result in the Table 9 reveals that the inference for the effect of modern beehive technology for both the groups remains same and has been allowed to differ in their probability to being treated 1 up to 3 with unobserved covariates. It implies that p-critical values of the entire outcome e^{γ} (Gamma) is log odds of differential due to unobserved factors where Wilcoxon significance level for each significant outcome variable is calculated. Values which is corresponds to each row of the significant outcome variables are p-critical values (or the upper bound of Wilcoxon significance level) at different critical value of variables are found significant which are estimated at various level of critical value of e^{γ}. This further indicated that the study considered important covariates that affected both household adoption of modern beehive technology and outcome variable. On the basis of these results, the study concluded that average treatment on treated (ATT) impact assessment are found insensitive to unobserved selection bias and is an absolute effect of modern beehive technology adoption.

Conclusions and Recommendations

This study aimed to evaluate the impact of modern beehive technology adoption on the income of households in the selected district of Oromia National Regional State, Ethiopia. The study employed two stage sampling techniques to select 384 sampled households. Chi-square test, t-test, logistic regression model and propensity score matching were employed to analyze the data. The result of chi-square test shows that there is statistically significant association between being adopter households and male headed household, access to training, access to beehive demonstration site visit and model farmer. Moreover, the result of t-test shows that there is statistically significant mean difference between adopter and non-adopter households in terms of age of household head, family size, beekeeping experience, frequency of extension contact, and education level of household head. This implies that there is a positive and significant relationship between being adopter of the technology and older farmer, large family size, having more experience in beekeeping, more frequency of contact with extension worker and attaining more education. The result of logistic regression revealed that frequency of extension contact, access to training, access to credit, age of household head, family size, beehive demonstration site visit and beekeeping experience had positive and significant effect on the household adoption decision of modern beehive technology. In addition, the results of propensity score matching indicate that households who were adopted modern beehive technology earned more income than non-adopter households. In order to increase the income of households' from honey production the concerned bodies should give due attention on how to expand modern beehives for smallholder farmers in the study area. This could be through improvement of credit services, extension services, training, experience sharing and expanding beehive demonstration site.

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