The Impact of Improved Beehive on Income of Rural Households: Evidence from Bugina District of Northern Ethiopia

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Abstract

Needless to say, increased adoption of modern beehives can improve the livelihood of smallholder farmers whose income largely depends on mixed crop-livestock farming. Owing to this, improved beehives have been disseminated to farmers in many parts of Ethiopia including Bugina district. However, its impact on the farmers income is less investigated. Thus, this study attempts to estimate the impact of adopting improved beehives on rural households' income and asset holding. Survey data was collected from 350 randomly selected households and analysed using an ESRM. The result has revealed that the adoption of improved beehives has enabled beekeepers to enjoy a higher annual income, and asset formation. On average, improved beehive adopters had earned about 6,077 (ETB[5]) more money than their counterparts. However, the impact of the adoption would have been larger for actual non-adopters, as reflected in the negative transitional heterogeneity effect of 1792(ETB). The result also has indicated that the decision to adopt or not to adopt improved beehives was subjected to individual self-selection. Improved beehives adoption also caused an increase in households' fixed assets, and can be used as an alternative poverty reduction strategy.

Keywords: impact, adoption, endogenous switching regression, income, and improved beehives.
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[5] ETB is the official currency of Ethiopia. In 2019, purchasing power parity for Ethiopia was 10.4 LCU per international dollars.

I. Introduction

Despite the growing prominence of innovation, limited studies examine the adoption of applications that support innovation processes. Regardless of the growing importance of innovation, however, limited studies have examined the adoption and impacts of applications of those technologies such as improved beehives.

Beekeeping is an especially important source of livelihood to resource-poor Ethiopian farmers and youths as it doesn't require large amounts of land, water, and fertilizer to thrive (Adimassu et al., 2017; Alemberhe & Gebremeskel, 2016; Anand & Sisay, 2011; Gebremedhin, 2015). It also provides essential ecosystem service of crop pollination that increases productivity and helps to maintain a balance between wild forest conservation and diversified agriculture (Alemberhe & Gebremeskel, 2016; Guesh et al., 2018). According to Alebachewu (2018) and Bareke et al. (2018), bees' pollination benefits crop production in Ethiopia with an estimated economic return of around $815.2 million which is 6.24% of the country's agricultural GDP.

Beekeeping can also be used as a climate adaptation mechanism at times of bad weather as bees can produce honey even with the little available rain (Thomas & Tounkara, 2020). Moreover, bee products can improve farm family nutrition and provide medicinal values.

Ethiopia is the leading honey and honey products producer in Africa. Being the first in terms of production and productivity (FAOSTAT, 2018), Ethiopia is the 10th largest honey producer globally (Sautier et al., 2018). The country has the potential to produce 500,000 tons of organic honey and 50,000 tons of beeswax whereas the country currently produces only 43, 000 and 3000 tons of honey and beeswax respectively per annum and its contribution to the national economy (GNP) is only around $1.6 m (Sautier et al., 2018). Although it is below its potential, honey production in Ethiopia has increased from 28,000 tonnes to 50,000 tonnes over the last 15 years period (Sautier et al., 2018). This wide gap between potential and the current capacity is mainly attributed to a lack of skill and awareness and use of modern technologies (Fenet & Alemayehu, 2016).

Among other things, the profitability of beekeeping is determined by the availability of improved bee technologies and improved management skill of beekeepers (Berhe et al., 2016; Kumsa & Takele, 2014). To this end, in the last fifteen years improved hives such as Kenya Top Bar (transitional) and frame hive have been introduced and in each year the government has disseminated a considerable number of improved (box) hives to farmers (Asmiro Abeje, *et al*. 2017; Kumsa et al., 2020). Hive type has been a significant effect on honey yield per hive (Haftom Gebremedhn, 2016). Improved beehive in this paper considers both Kenyan Topbar (Transitional) and modern beehives.

According to CSA (2008), there are about 4,601,806 beehives in the country out of which about 95.5% were traditional, 4.5% improved (4.3 % transitional and 0.20% frame hives). under Ethiopian farmers' management condition, the average amount of crude honey produced from the traditional hive is estimated to be 5-10 kg/hive/year which is much lower than the amount that could be produced by using improved beehives According to(Fikadu et al. 2017). The estimate is to reach 20-30 kg per colony per year.

The semi-arid of the Eastern Amhara area is delineated as the potential beekeeping site of the government (Alemu et al., 2013). Despite the potentials and prospects of beekeeping in the area, little is known on technology adoption impact on annual incomes of rural beekeepers.

The population of the Bugina district is growing quickly. It is doubling almost every quarter of a century (CSA, 2011). This has a negative effect on landholding and other natural resources because man to land ratio has increased significantly. However, according to Bugina District Livestock and Fishery Resource development department (2018), the diffusion and spread of affordable improved beehives such as 215 Kenya Top Bar (Transitional) and 3254 framed (boxed) beehives are expected to boost harvests and family incomes. But there is conflicting information between the actual performance of improved hives and their claim of success by its promoters. Some researchers such as Asmiro Abeje, and his colleagues (2017) have dealt with this district to assess the adoption & intensity use of modern beehive with its determinant factors, and to analyse factors affecting adoption of modern beehive & to identify the constraints of modern beehive adoption. However, they have not been able to address the adoption impact on beekeeper`s annual income. Therefore, this study ought to analyse the impact of adopting improved beehives on the income of beekeepers in the said study area.

2. Materials and Methods

2.1 Study Area

The Bugina district is one of the fourteenth (eleven Rural and three Urban) districts in the North Wollo Zone of Amhara regional state, According to FSCDPO (2011). The altitude of the district ranges from 1336 and 2827 m.a.s.l. The Annual temperature and rainfall vary between 7.5 ºc to 26 ºc; and750 mm to 1162 mm respectively.

In the semi-arid part of the Amhara region, including Bugina district, large areas of inaccessible lands for crop cultivation and livestock grazing (along escarpments, hills, and rising and falling mountains) are covered with various types of bushes, which are potential for beekeeping (Aynalem & Mekuriaw, 2017). The district is among the potential beekeeping districts in Wag-Himra administrative zone as it is identified by the regional government (Alemu et al., 2013).

Data Source and Collection Tools

The study has employed household-level cross-sectional data collected using face-to-face interviews. We have used a multi-stage sampling method for selecting representative sample households from the population. In the first stage, eight sample *Kebeles*[6] from thirteen available have been randomly selected.

The estimated total population (households who practice beekeeping Bugina) were 1817 of whom 999 (55%) were non-adopters and 818 (45%) were adopters. For sampling in the second stage, 350 total households from the two groups were selected using a sample size determination formula. Since the target population is less than 10,000, we used (Cochran, 1963) sample size determination formula.

$$n_0 = \frac{z^2pq}{e^2} \quad \textbf{(1)}$$

Where n_0 is the sample size, $z^2$is the abscissa of the normal curve that cuts off an area α at the tails (Suppose the researcher wishes to have a 95% confidence level (Z), e is the desired level of precision (0.05), p is the estimated proportion of expected adopters (0.45), and q is 1-p (0.55). Therefore, n_0 =380. Then,

[6] Lower administrative unit

n =314; where n is the desired sample size, but additional 36 observations were included to compensate potential observations to be discarded for any reason during data clearance. Hence, the actual sample size of the study conducted was 350 (156 users and 194 non-users) respondents. The number of the adopter and non-adopter samples was determined by using their proportion from the total population.

2.2 Methods of Data Analysis

Descriptive statistics, inferential statistics, and econometric models have been used to address the study objectives. The endogenous switching regression (ESR) model has been used for evaluating the impact of modern beehive adoption on the outcome variable, which is income in this case.

The decision to adopt or not to adopt an improved beehive is left to be on volunteer bases and may also be based on individual self-selection and preference (Di Falco *et al*., 2011) beekeepers that adopted may have systematically different characteristics from the beekeepers that did not adopt. Unobservable characteristics of beekeepers may affect both the adoption decision and the income earned from beehives, resulting in inconsistent estimates of the impact of adoption on beekeepers. To this end, endogenous switching regression by full information maximum likelihood (FIML) was used to account for potential Endogeneity problems.

The ESR model is estimated using two-stage regression. In the first stage, a value of 1 or 0 is assigned to represent the choice of whether a household decides to use an improved beehive. We specified the mode for the selection equation for improved beehive adoption as:

$$S_i^* = Z_i \alpha + u_i \text{ with } S_i = \begin{cases} 1 \text{ if } S_i^* > 0 \\ 0 \text{ other wise} \end{cases} \qquad (\mathbf{2})$$

Following Di Falco et al., (2011), the second stage of an endogenous switching regression (ESR) model can be specified in two regimes: (1) to adopt and (2) not to adopt as follows.

Regime 1: $y_{1i} = X_{1i}\beta_1 + \varepsilon_{1i} (3a)$
Regime 2: $y_{2i} = X_{2i}\beta_2 + \varepsilon_{2i} (3b)$

Where S_i is a dichotomous variable representing a participation of rural beekeepers in improved beehive adoption; z_i refers to vectors that affect rural beekeeper`s decision to adopt improved beehive, X_i represents a vector of explanatory variables which determines the amount of income gained annually. Even though Z and X may overlap, but there must be at least one variable (instrumental variables) in Z is required not to be included in X to properly identify the outcome equations, latent variable (S_i^*) represents the expected benefits of adopting as compared to not adopting; parameter α represents coefficients for the row vectors to be estimated, and α and β are a vector of unknown parameters to be estimated. y_{1i} and y_{2i} are outcome variables (i.e. total amount of money generated in the year) in regimes 1 and 2 respectively, and the error terms (ε_1 & ε_2) in the continuous outcome equation and u_i in the selection equation. Finally, the error terms are assumed to have a trivariate normal distribution, with zero mean and covariance matrixΩ; i.e., (ε_1,ε_2 $\cup_2$) $N \sim(\mathbf{0},\Omega)$. This model is defined as a "switching regression model with endogenous switching" (Maddala & Nelson, 1975).

The specification was chosen for the income-generating equations (3a) and (3b), which follows the common practice in the agricultural economics literature (Coelli and Battese, 1996), allows us to use as exclusion restrictions the variables related to the beekeeper household`s level of perception, and characteristics.

The ESR model can be used to compare the expected income of the beekeepers under four scenarios: (a) observed income of actual adopters (b) observed income of non-adopters (c) the expected income that adopters would get if they don't adopt, counterfactual (d) the expected income that non-adopters would get if they adopt, counterfactual. The conditional expectations for income-earning in the four cases are presented and defined as follows;

$E(y_{1i}|s_i = 1) = X_{1i}\beta_1 + \sigma_{1u}\lambda_{1i}$ (4a) (predicted outcome of adopters should they have adopted)

$E(y_{2i}|s_i = 0) = X_{2i}\beta_2 + \sigma_{2u}\lambda_{2i}$ (4b) (predicted outcome of non-adopters if they had not adopted)

$E(y_{2i}|s_i = 1) = X_{1i}\beta_2 + \sigma_{2u}\lambda_{1i}$ (4c) (predicted outcome of adopters had they not adopted)

$E(y_{1i}|s_i = 0) = X_{2i}\beta_1 + \sigma_{1u}\lambda_{2i}$ (4d) (predicted outcome of non-adopters had they adopted)

Table 9: Conditional Expectations, Treatment, and Heterogeneity Effects

Sub-sample	Decision stage		Treatment Effect
	To adopt	**not to adopt**	
Farm households who adopted	(a) $E(y_{1i}\|s_i=1)$	(c) $E(y_{2i}\|si=1)$	ATT
Farm households who did not adopt	(d) $E(y_{1i}\|si=0)$	(b) $E(y_{2i}\|si=0)$	ATU
Heterogeneity effect			ATH

Source: Adopted from Di Falco et al. (2011)

Cases (4a) and (4b) in Table 1 represent the actual expectations observed in the sample. Cases (c) and (d) represent the counterfactual expected outcomes observed in the sample.

S_i=1 if the beekeeper adopt; S_i= 0 if the beekeeper does not adopt, y_{1i} = income of the beekeeper, if the beekeeper adopt. y_{2i} = income of the beekeeper if the beekeeper does no adopt.

Where y1i stands for adopters' annual income, si =1, is the decision to adopt improved beehive y2i stands for non-adopters' annual income, si =0, is the decision not to adopt

y2i stands for adopters' annual income, si=1 if adopters decided to not adopt

y1i stands for non-adopters' income, si=0, if non-adopters decided to adopt

Following Heckman et. al (2001), the average treatment effect of adopting improved beehives on the treated (ATT) can be estimated as a difference between (a) and (c) – i.e. $\mathrm{ATT} = \mathrm{a} - \mathrm{c}$. The ATT represents the impact of improved beehive adoption on the income of households that adopted improved beehives. Similarly, we calculate the impact of the average treatment effect on untreated (ATU) as a difference between (d) and (b) – i.e. $A\mathrm{TU} = \mathrm{d} - \mathrm{b}$.

As a final point, we investigate the average "transitional heterogeneity" (ATH) that examines whether the impact of adopting improved beehive is larger or smaller for the beekeeper households that actually adopted or for the beekeeper household that actually did not adopt in the counterfactual case – i.e. $\mathrm{ATH} = \mathrm{ATT} - \mathrm{ATU}$.

2.3 Variables and their Definitions

Below are the variables used in the participation equation, outcome equation and dependent variables are defined.

Dependent variables

Participation Decision: is the dummy variable that represents the participation of the households in improved beehives.

Outcomes variable

Annual income (AI): is the amount of money in Ethiopian Birr (ETB) generated within a year from several income sources.

Fixed Asset Value (AV): beekeepers' physical assets (such as build houses, livestock breed, electronics, bee colony, and farm materials like motor pumps,) are among the asset that evaluated by the local market price during the survey period measured in ETB.

Independent variables

The selection of the variables used in this study is mainly based on an empirical literature review. Table 2, below, presents the variable used in the adoption decision.

Table 2: The definition of variables used in adoption of improved beehives

Variable code	Type	Definition of variables	Measurement	Hypothesis
AgeBK	Continuous	Age of household Head	year	±
AgeBK2	Continuous	Age Square of household head	year	-
SexBK	Dummy	Sex of household Head	1 if Male 0 otherwise	+
AdualtEqu	Continuous	family size	Number	+
EduLevl	Dummy	Education status	1 Literate 0 Iliterate	+
LandSz	Continuous	Land size in hectare	Ha	
AcsCrdS	Dummy	Access to Credit	1 if yes 0 otherwise	+
ExtCont	Dummy	Access to Extension contact	1 if yes 0 otherwise	+
Gofincom	Dummy	Off-farm income	1 if yes 0 otherwise	+
TLU	Continuous	Livestock owned	Number	+
MBClimcr	Dummy	Households' perception of Modern beehive adaptive capacity to climate change	1 if yes 0 otherwise	+
ResdYr	Continuous	Beekeeper's stayed in their prior residence in year	Year	+

3. Result and Discussion

3.1 Socio-demographic Characteristics

From the total sample, 156 (44.5 %) were adopters of improved beehive while 194 (55.5%) were non-adopters. It is also found that 95.7% of them are men-headed while 4.3% are women-headed households. Only 2 % of the adopter households were headed by women and the remaining 98% by men. Likewise, there is a significant association between improved beehive adoption and literacy as 24 % of non-adopters and 56 % of the adopters can at least read and write with basic arithmetic skills.

Similarly, the survey result showed 55% of the adopters and 45% of the non-adopters have got extension service. Extension service here refers to advice, training, demonstration related to improved beehive construction and utilization. There is a significant association between the adoption of improved beehives and access to extension service. More adopters (53%) as opposed to only 47% of the non-adopters perceived that improved beehives are better in reducing the effect of drought on beekeeping as compared to the traditional ones Table 3.

Table 3: Summary of descriptive statistics for discrete variables by adoption

Variables	Values	Non-Adopters		Adopters		Total Sample		χ^2-Value
		N(194)	%	N(156)	%	N(350)	%	
SexHHH	Men	182.00	93.8	153.00	98.0	335.00	95.7	3.83**
	female	12.00	6.19	3.00	1.92	15.00	4.29	
ExtCont	Don’t access	78	40.21	12	7.69	90	25.3	47.85***
	Access	116	59.79	144	92.3	260	74.3	
ClimPerc	Not perceive	152	78.35	74	47.4	226	64.6	36.12***
	Perceived	42	21.65	82	52.6	124	35.4	
EduLevl	Illiterate	147	75.77	69	44.2	216	61.7	36.4***
	Literate	47	24.23	87	55.8	134	38.3	
Off-inco	No	117	60.31	70	44.9	187	53.4	0.1041*
	Yes	77	39.69	86	55.1	163	46.6	
AcsCrdet	Don’t access	189	59.62	128	40.4	317	90.6	23.93***
	Accessed	5	15.15	28	84.9	33	9.43	

Source: Computed from own survey data, (2018) Moreover, the livelihood of households within the farming community has been found to depend on a diverse set of income sources. Farmers in the study area are reported to earn income both from the farm and off-farm activities. The mean annual income of sample households is found to be ETB 13544.26 where there is a significant difference in mean annual income between adopters (ETB 19189.28) and non-adopters (9004.96). The chi-square (χ^2) analysis also revealed a significant mean annual off-farm income among the adoption groups in favour of the adopters. The chi-square test result also showed an association between access to credit and adoption were significantly associated.

On one hand, the age of the sample household heads ranged from 20 to 78 years with a mean of 48.8 years. On the other, the average number of economically active family members for adopters and non-adopters was 3.9 and 3.5 respectively with a significant mean difference Table 4. Similarly, the mean livestock holding of sample households was 4.48 TLU.

The average total land holding of the surveyed households has estimated to be 1.53 hectares with 1.37 hectares for adopters and 1.66 hectares for non-adopters with a significant t-value (Table 4). This result has shown that beekeeping does not require a huge land holding. To thrive as beekeepers, sufficient and fertile land would tend to consider beekeeping as a side-line practice rather than hugely investing labour and capital in modern beekeeping. However, a few Empirical studies stated that farm size does not affect the adoption of an improved hive (Wodajo, 2012).

Table 4: Summary of descriptive statistics for continuous variables by adoption

Variables	Non-Adopters (N=194)		Adopters (N=156)		Total sample (N=350)		T-value
	Mean	st.dev	Mean	st.dev	Mean	st.dev	
AgeBK	49.44	11.86	48.10	10.67	48.84	11.35	1.095
AdualtEqu	3.54	1.24	3.89	1.40	3.69	1.32	-2.535***
TLU	4.45	3.05	4.50	2.66	4.48	2.88	-0.166
ResdYr	13.16	7.47	39.04	16.18	24.7	17.70	-19.82***
LandSz	1.66	1.18	1.37	0.74	1.53	1.02	2.71***

Source: Computed from own survey data, (2018)

Note: *** represent statistically significant at 1% significance level.

Beekeepers' income source

In the study area, respondents depend on agriculture for their livelihood, employment, income earnings, food, and non-food production and consumption. Crop income (irrigated and rain-fed crops), off-farm, non-farm income, and income from livestock were the source of income in the study area. As stated in (Table 5), In the study area, as it is observed from the survey results the relative share of income from bee product to the total annual household income is the largest. Hence, beekeeping is the most important source of income in the study area. It is followed by livestock production, non-farm, and off-farm respectively. However, income from crop production is the lowest which indicates the absence of surplus cereal production.

Table 5: Beekeeper income comparison level by ETB

Income gained from	User (N=156)	Non –user (N=194)	Combined	Difference	T-test
	Mean	Mean	Mean	Mean	
Crop income	573	304	424	269	-1.86*
Off-farm income	880	344	583	535	-2.12**
Non-farm income	1929	591	1187	1338	-3.86***
Livestock income	5318.8	5242.9	5276.7	76	-0.2
Bee product income	10488.38	2522.59	6073	7966	-14.9***
Total income	19189.28	9004.96	13544.26	10184.32	-11.4***

*** $p<0.01$, ** $p<0.05$, * $p<0.1$ represents levels of significance.

Improved beehive adopters have significantly (1% levels) higher farming income & total income than non-user beekeepers. The survey result has revealed that the mean annual bee product income of the users was ETB 10488 (315%) higher than non-users (Table 5).

Beekeepers' Physical Asset Value

Household assets are vital resources for livelihood improvements. Similar to natural capital, access and owing physical assets were found to be an essential variable towards the enhancement of households' livelihoods (Abdelhak et al., 2012). It is difficult to determine the resale values of assets accurately. Respondents were asked to list their assets and evaluate the current local market value during the survey period. As shown in (Table 6) the mean asset value of beekeeper assets owned by the user is ETB 143750.3 (357%) higher than the non-user. The t-test result has revealed that the asset holding between the user and non-user has been found to be significant at 1% level confidence relative to the comparison group whose asset ownership is concentrated in the basic household items. This result shows that the adoption of improved beehive allows beekeepers to promote and expand their assets and activities which in turn improve their livelihood.

Table 6: Asset possession mean comparison

Variable	**User (N=156)**	**Non –user (N=194)**	**Combined**	**Difference**	**T-test**
	Mean	Mean	Mean	Mean	
Asset Value (AV)	143750.3	31397.52	81474.74	112352.7	-14.86***

* p<0.1 represents levels of significance.

3.2 Results of the Econometric Model

Factors influencing adoption of improved beehives

The study results (Table 7) have indicated that the level of education, the active labour force in terms of adult equivalent, access to credit and extension service, and beekeepers stayed in their prior permanent residence are determined by the probability of households' participation in improved beehive adoption. C*eteris paribus*, educated household heads have a 23% more chance of adopting modern beehives than illiterate ones. This result has expected that education must play a role in raising the ability to access and use information thereby improving people's awareness for informed decision making. The result is in line with previous results done by (Affognon et al., 2015), (Adgaba et al., 2014), and Tadele Adisu Haile Selassie, 2016).

Availability of family labour force has affected the adoption of improved beehive positively and significantly. This implies that labour is one of the most extensively used inputs of agricultural production including beekeeping in the study area. Farmers with large family size in terms of adult equivalent might significantly adopt the technology to satisfy the immediate need of their family.

Hence, it was hypothesized that households with a large family would adopt the technology more those that are not. The result is consistent with the findings of (Adgaba et al., 2014), (Ajao & Oladimeji, 2013), (Bekuma, 2018), and (Tadele Adisu Haile Selassie, 2016). On the other hand, access to extension service and credit has influenced the farm households' participation in improved beehive adoption positively. These results are confirmed with the findings of previous studies (Ajao & Oladimeji, 2013), (Affognon et al., 2015).

Table 7: ESR factors affecting adoption of improve beehive

Variables	Coefficient.	Robust Std. Err.	P>z
SexBK	.576	.541	0.286
AgeBK	-.082	.081	0.311
$AgeBK^2$	.0006	.0008	0.470
EduLevl	.592	.223	0.008
AdualtEqu	.214	.104	0.040
LandSz	-.007	.031	0.811
Gofincom	-.116	.274	0.672
TLU	-.008	.050	0.875
ExtCont	1.31	.315	0.000
AcsCrdS	1.162	.432	0.007
ResdYr	.091	.011	0.000
MBClimcr	.159	.236	0.497
_cons	-2.888	1.941	0.137
chi2(1)	8.62***		
Observation	350		

***, **, and * refers to statistical significance at 1%, 5%, and 10%.

Source: Computed from own survey data, (2019)

ESR model estimates the impact of improved beehive adoption on income & asset

According to Table 8, out of the total eleven explanatory variables, output for the income /outcome equation of the model, five variables are found to be significantly determinants of household income. These are the education level of beekeepers, cultivated land size, income-generating other than beekeeping, livestock holding, access to extension contact, and access to credit service. In general, the sign of coefficients of all variables have taken the researchers' prior expectation. Sex of beekeeper, beekeeper's education level, and extension contact on users, cultivated land size and off-farm income on non-users, and livestock holding on both (user & non-user) beekeepers' asset-building had significant effect with this concise background, the effect of the significant explanatory variables on beekeeper rural farm households' income level is discussed below.

Education is found to have a positive and significant influence on the income of households and livelihood improvement, and it is statistically significant at 1% level of significance. As hypothesized, its coefficient had a positive sign. Indeed, if the education of beekeeper household head raised by one level, beekeepers' income would rise approximately by 16.2% more than non-literate beekeepers while other variables keeping constant. The result of this finding is that education leads to proficient household management and, significantly improves economic performance as a whole. Similarly (Jehovaness A., 2010) suggests that the productivity of individuals with a higher level of education who are engaged in any agricultural activity is likely to be higher than that of less-educated farmers.

Cultivated land size: it was positively and significantly affected for both the non-user and user income at a 10% significance level. Households have cultivated land who can produce a relatively sufficient amount of crop on their own or through different contractual agreements such as sharecropping.

Income-generating other than beekeeping: it is found to have a positive and significant influence on the income of households, and it is statistically significant at 1% and 10 % level of significance respectively for non-users and users. This shows that non-farm income has a significant effect on the income of non-users' beekeepers more than the users one. Similarly (Abraham Gebrehiwot, *et al.*, 2015) households' engagement in other income-generating activities might not have a higher probability of participation in agricultural technology adoption in a sense that the households with larger other income might not necessarily participate in beekeeping practice.

Livestock holding measured in Tropical Livestock Unit (TLU) is found to have a positive and significant influence on income and asset formation of households, and it is statistically significant at a 1% level of significance. It contributes to total household income directly through the sale of livestock and their products, and indirectly through use as a source of draught power for crop production activities. Moreover, Livestock has a direct role in raising agricultural productivity that can help households stabilize consumption by absorbing income shocks that might arise from crop failures triggered by natural disasters. Oxen are the sole draught power sources and hence lack of oxen besides its negative effect on land productivity, it also signifies a lower economic status of farm households. A similar result was reported by other studies (Abraham Gebrehiwot, *et al*., 2015), (Bekele Shiferaw, *et al*., 2014), and (Menale Kassie, *et al*., 2014)

Access to credit affected user household income-generation positively and significantly at a 1% significance level. The positive sign indicates that household who uses credit does initiate investment in farm and non-farm practice for their income-generating activities (IGA) and it enables the beekeeper households to purchase farm inputs such as bee colony, improved beehive and other necessary accessory timely which all makes the production and productivity of an apiary or bee yard increases on a given farm plot. This is consistent with other studies such as (Ajao & Oladimeji, 2013), (Aikaeli, 2010).

The result of σ_{1u} (0.36) and σ_{2u}(0.41) represent the covariance of the selection and the outcome equation of adopters and non-adopters respectively, which is non zero and positive indicates the presence of endogeneity. That is to say, we can conclude to reject the null hypothesis of the absence of sample selectivity biased.

In addition to the endogeneity test, ρ_j (correlation coefficient between the error term in selection equation with outcome Equation (1) i.e., adopter (-0.42), and with outcome Equation (2) i.e., nonadopter (0.58) provide economic interpretation depending on their signs. The opposite signs indicate that users enjoy above-average income and fixed asset holding once having improved beehive. The coefficient $\boldsymbol{\rho}1$ and $\boldsymbol{\rho}2$ can give evidence for model consistency under a condition $\boldsymbol{\rho}1$ (-0.42) < $\boldsymbol{\rho}2$ (0.58) or σ_{1u} (0.36) is < σ_{2u} (0.41). This implies that the user enjoys income and fixed asset level than they would if they did not have to adopt (Trost, 1981).

The parameter has a negative sign in the equation for adopters, implying that beekeepers that adopt improved beehives have a significantly higher income more than a beekeeper who is randomly selected from the sample.

Table 8: Endogenous switching regression model estimates for the outcome equation

Variable	Income (AI)		Asset Value (AV)	
	Non-User	User	User	Non-User
SexBK	-0.117	0.0946	0.929**	0.113
	(0.131)	(0.211)	(0.436)	(0.098)
AgeBK	0.0103	0.00677	0.0103	0.00292
	(0.0194)	(0.0125)	(0.0257)	(0.0144)
AgeBK2	-0.000136	-3.57e-05	-8.94E-05	-4.99E-05
	(0.000190)	(0.000116)	(0.000238)	(0.000141)
EduLevl	0.0187	0.181***	0.208*	0.0477
	(0.0726)	(0.0658)	(0.133)	(0.0543)
AdualtEqu	0.0387	0.0154	0.0555	0.00556
	(0.0297)	(0.0252)	(0.0516)	(0.0222)
LandSz	0.0133*	0.00356*	0.0159	0.00986*
	(0.00744)	(0.0115)	(0.0233)	(0.00553)
Gofincom	0.348***	0.151*	0.0235	0.0994*
	(0.0752)	(0.0828)	(0.17)	(0.0562)
TLU	0.0906***	0.0355***	0.0524*	0.0301***
	(0.0120)	(0.0131)	(0.0272)	(0.0089)
ExtCont	0.00532*	0.0613*	0.238*	0.049
	(0.0654)	(0.112)	(0.0229)	(0.0478)
AcsCrdS	0.228	0.215***	0.259*	0.0515
	(0.192)	(0.0806)	(0.0164)	(0.148)
Constant	7.798***	8.634***	9.069***	9.603***
	(0.457)	(0.420)	(0.87)	(0.34)
σ_i	0.41**(0.024)	0.36**(0.020)	.75***(.042)	.304***(.015)
ρ_i	0.59**(0.18)	-0.43**(0.20)	-.414**(.179)	-.0135*(.173)
Observations	194	156	156	194
LR test of indep. eqns. :		ESR		
chi2 (1) 8.6**		Wald chi2 (11) 110.7***		
Log likelihood 239.35		Number of obs = 350		

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Source: own survey result, (2018)

Table 9 presents the average treatment effect of adopting improved beehives on smallholder's income and asset formation. The average expected income earned per household per year for households that adopted improved beehives is estimated to be16, 566 ETB, while it is about 6848 ETB for those households that did not adopt the entitative. T, and the average asset values for the adopters is 119158.3 ETB while 28213.45 ETB for non-adopters. This simple comparison, however, may mislead to conclude that on average the adopter households earned about 9718 ETB (that is 141.91 %) more income than the households that did not adopt, and 90944.85 ETB (322%) more average asset value than non-users. Hence, the counterfactual case (c), and (g) in income and asset equation referring to the income and asset of beekeepers who actually adopted would have earned if they don't adopt was used as a comparison group. Accordingly, compared to the counterfactual (10489.47 and 44995.07 ETB) actual adopters have earned an additional 6076.97 ETB and 74163.25 ETB income and asset value, implying that adoption of improved beehives leads to 57.93 % and 164.8% income and asset value increment respectively.

Table 9: Impact of adopting improved beehive: treatment effect, and heterogeneity effect.

Outcome Var.	Sub-sample	Decision stage		Treatment effect
		To adopt	Not to adopt	
Annual income	Beekeeper's who adopted	(a) = 16566.44	(c) = 10489.47	ATT= 6076.972
	Beekeeper's who did not adopt	(d) =14717.39	(b) =6848.072	ATU=7869.316
	Heterogeneity effect			TH=-1792.34
Asset Value	Beekeeper's who adopted	(e) = 119158.3	(g) = 44995.07	ATT= 74163.25
	Beekeeper's who did not adopt	(h) =92442.4	(f) =28213.45	ATU=84228.99
	Heterogeneity effect			TH=-10065.7

Source: computed from survey data (2018)

Likewise, the ATU value can be interpreted as actual non-adopters would have earned 7869 & 84228.99 ETB more income and fixed asset value if they decide to adopt. Here it is important to note that the impact from adopting a beehive is even higher for actual non-adopters in the counterfactual case. This is clearly shown in the average transitional heterogeneity effect i.e., the impact of adopting improved beehives on income and asset value is smaller by 1792.34 and 10065.7 ETB for households that did adopt as opposed to those who did not respectively. These results imply that there are systematic socioeconomic different characteristics between the two groups, and self-selection is biased on technology adoption. It also indicates that resolving barriers to adopting beehives would help to improve the overall income and livelihood of the community at large.

4. Conclusion and Recommendation

This study has analysed the determinants of households' decision to adopt improved beehive and its impact on their annual income and asset value. The study was done in Bugina district, northern Ethiopia in eight honey-producing randomly sampled *Kebeles*. Of the total 350 sample households, 44.57% of them were adopters.

Based on the results of this study, three main conclusions are drawn. First, the group of households that did adopt beehives has systematically different characteristics as opposes to the group of beekeeper households that did not adopt. Second, the adoption of improved beehives increased beekeepers' income and fixed asset formation; however, beekeepers who have decided to adopt are likely to have higher income and fixed asset value compared to actual non-adopters. Third, the transitional heterogeneity impact of adopting improved beehives on beekeeper's income and the fixed asset value is smaller for households that adopt than for the rural beekeeper households that did not adopt in the counterfactual case (i.e. if non-adopters were adopted), on the other hand, the negative sign of transitional heterogeneity indicates the presence of improved beehive adoption biased (self-selection or non-randomized) problems. These results are particularly important to design effective adoption strategies to fully realize the potential impacts of improved beehive adoption on the income and overall livelihood of rural beekeeper households. However, sustainable returns to beehive adoption are influenced by the education level, beekeepers' stability on their prior residence, credit service, extension contact, and beekeepers' perception towards improved beehive comparative advantage. Therefore, effective access to education, credit service, extension service, and awareness creation will facilitate adoption participation and thereby income and fixed asset formation of rural beekeepers.

However, the authors point out that the modernization of production, the education of beekeeper improvements are essential parts of the increased competitiveness of the sector. The authors stress the necessity of improving all the factors of competitiveness in the apiculture sector, with their economic strength and the level of the commercial attitude.

Although the study has revealed that adoption of improved beehive could increase rural beekeeper‘s income, and fixed asset formation, there is no sufficient, protective, and sustainable shade. Due to this with climate variability bees absconding faced, even for those who take part in adoption. Therefore, the district or regional level government has to encourage adult education, awareness creation via frequent extension package, and material support to beekeepers to undergo expanded improved beekeeping practice. It is recommended that the responsible body to work hard on the rural beekeepers to aware of the comparative advantage of the improved beehive. The government should support and encourage rural farmers to be stable within their prior residence. Furthermore, returns to adoption are influenced by the credit access, in part because of the lack of initial capital for input and accessory purchase the beekeepers faraway to adopt in turn to pick up their income. Therefore, effective access to education level, active labor force, credit, and extension service will facilitate adoption participation.

Since the study has directed its resources exclusively among the members of the society of beekeepers in the specific district of “Northern Ethiopia”, it is questionable if the conclusions could be generalized to be taken as representative. The researchers suggest that similar research be carried out in different locations of the country and in different beekeeping societies, to establish other possible influences. Then, the findings of the study could be compared to the sociocultural factors in different regions and the beekeepers’ willingness to adopt new beekeeping technologies or professional advice from specialized bodies.

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