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Analysis of Factors Influencing Intensity of Adoption of Modern Box Hive Technology by Smallholder Farmers in Central Zambia

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Abstract: *Honey production in Zambia, has been below full potential due to some socio-economic, demographic, institutional and environmental related factors. This study was undertaken to identify factors influencing adoption of improved box hive such as Top-bar hives technology among small-scale farmers in Kapiri Mposhi district of Central Province in Zambia. Data collected from a sample of 98 small-scale beekeeping households was analyzed using descriptive statistics and count data regression analysis. The negative binomial regression results revealed that household size, farmer's education level, training in beekeeping, and extension contact are statistically significant and positively influence the number of improved hives adopted by the farmers in the study area. Whereas, the number of traditional hives owned has negative effect on intensity of adoption of improved hive technology. The study suggests that policy interventions that aim at improving access to extension, beekeeping training programs, education and access to improved hive technology through access to credit are crucial to enhancing intensity of technology adoption among smallholder farmers.*

Keywords: *Honey, adoption, socio-economic factors, Poisson, negative binomial regression*

1. Introduction

Beekeeping provides various benefits such as income from the sale of bee products, self-employment opportunities, pollination and conservation of biodiversity (Al-Ghamdi, 2017). In Zambia, beekeeping is seen as a viable business that can improve and diversify incomes of rural households. It also offers an alternative livelihood to forest dependent communities which help reduce deforestation by conserving trees for beekeeping and discouraging charcoal production.

Zambia given its ample endowment of flora and fauna has good potential for beekeeping and honey production. There are about 30,000 smallholder beekeepers across the country and are concentrated mainly in North Western, Western, Central and Copperbelt provinces. The country's annual production of honey is 2,000 tonnes and improved access to lucrative markets can propel production to 10,000 tonnes (ITC, 2015). Industry experts have commented that Zambia is underperforming its capacity since solely in the North Western province, there is a capacity potential of 30,000 tonnes per year (Zambiainvest.com, 2016).

Although there has been some efforts to promote beekeeping and honey production through various projects by Government and Non-governmental organizations, 85% of beekeepers in Zambia still practice traditional beekeeping methods such as use of bark hives while 15% are modern beekeepers who use modern wooden hives such as the Kenyan Top-bar (Husselman, et al., 2009; SNV, 2014). The use of traditional beekeeping methods contribute to low yield and low honey production in the country.

A number of studies in other developing countries have found that honey production is affected by socio-economic, demographic, institutional and environmental related factors. These studies include works of Masuku et al. (2013); and Majuni et al. (2012). The socio-economic factors are important in the design of appropriate policy measures to improve beekeeping and honey production. In Kaduna state of Nigeria, Ojo et al. (2017) found that production of honeybee products was constrained by lack of equipment, lack of technical knowledge, inadequate knowledge of values of other honeybee products aside honey and beeswax and unassured market.

In Eswatini (i.e. former Swaziland), honey production was positively and significantly influenced by experience of beekeepers in honey production and size of the colony (Masuku, 2013). Meanwhile in

Uganda, adoption of beekeeping was significantly affected by access to credit, extension services, phobia for bee stings, starting capital to buy hives and equipment, and lack of land for setting apiary (Mujuni, et al., 2012). A study by Kalanzi et al. (2015), found that adoption of improved beehives was influenced by education and training in beekeeping. Moreover, honey production was dependent on the use of traditional beehives, and identified constraints included pests, lack of equipment, farm sprays and low prices for bee products. Workineh (2011), also found that credit, knowledge on practical activities of the technology, education level of household head, positive perception on modern beehive technologies and apiary visit demonstration were most determinant factors of adoption of improved box hive.

A key factor in improving the production and productivity of honey production lies in the adoption of improved beehives such as the Top-bar or box hive technology (Tadesse, et al., 2021). Despite the potential benefits of adopting the improved hive, the adoption and intensity of adoption of these technologies has remained low in Zambia. Although various studies reveal that socio-economic factors are important determinants of beekeeping and honey production, in Zambia, there is limited information on how various socio-economic factors influence honey production among small-scale beekeepers. Therefore, to fill this information gap, and to inform the design and implementation of effective policy measures for enhancing honey production among small beekeepers, this study was initiated. The study objective was to examine the socio-economic factors affecting beekeeping and honey production in Zambia. To make informed decisions regarding the development of beekeeping and honey production, a deep understanding of the factors affecting the sector was needed. Thus, it was essential to assess the socio-economic factors affecting honey production among beekeeping households in Zambia and identify their major constraints. According to SNV (2014), 39% of beekeepers in Zambia are affiliated members of 43 beekeeping cooperative units distributed in major apicultural districts. Mwinilunga, with 6,000 beekeepers has the largest number of members, followed by Zambezi (2,000), Kapiri Mposhi (1,883), Kabompo (1800), and Mkushi (572) to mention the top five. This study was conducted in Kapiri Mposhi, one of the largest beekeeping districts in the country, and it is located in Central province of Zambia. Although there is great potential for beekeeping in Kapiri Mposhi district of central Zambia, honey production has been below potential due some socio-economic, demographic, institutional and environmental related factors. Thus, Kapiri Mposhi district was appropriate as a case study.

2. MATERIALS AND METHODOLOGY

Description of the study area

The study was conducted in Kapiri Mposhi District that is situated at 13°97´S; 28°66´E, 1286m above sea level in Central Province, it covers area of 15,000 Km² and has a population of about 253,786 inhabitants (CSO, 2010). The district is 200 Km north of Lusaka, the capital of Zambia. The district was purposely selected in the province because of high concentration of beekeepers and high honey production potential in particular around the Luanshimba area in Mulungushi block. In Kapiri Mposhi district honey trade takes place at roadside stalls all year round. The district is situated in agro-ecological region II with average annual rainfall of 1000 mm. The temperature in the area ranges between 17 to 33 degrees Celsius, making it suitable for beekeeping (Chidumayo and Gumbo, 2010). The main vegetation type is Miombo woodland which provide flowering plants from which honeybees feed on nectar and pollen. Agriculture is the main source of livelihood for majority of the population in the district. Important crops grown include maize, groundnuts, sweet potatoes, cotton, water melon, and other vegetables. Kapiri Mposhi is divided into six agricultural blocks namely; Changondo, Chipepo, Lukanga, Lunchu, Mulungushi and Nkole which are further subdivided into 32 agricultural camps (Kabamba and Muimba-Kankolongo, 2009).

Data collection

Purposive sampling and multi-stage random sampling techniques were used in selecting respondents. First the district in the province was purposively selected based on high honey production potential. Secondly, Mulungushi block was purposively selected out of the six agricultural blocks in Kapiri Mposhi district. Thirdly, 100 beekeepers were randomly selected from six agricultural camps in Mulungushi block. The sample comprised of 32 respondents from Luanshimba agricultural camp, 29 from Kakulu camp, about 10 respondents per camp in Kaunga, Imansa, Kamboshya and Lukanda. The beekeepers were interviewed using a questionnaire. Additional information on beekeeping was obtained through interviews with key informants in the study area. Out the sample, 98 useable questionnaires were used in the data analysis.

The data collected included: demographic characteristics of the beekeepers (e.g. age, education, gender, family size, and experience), beekeeping characteristics (e.g. type of hives used, number of hives, and quantity of honey harvested, access to information, extension, credit, and group membership and constraints to beekeeping in the study area. The study was conducted in between February and March 2017.

The data was also checked for presence of multicollinearity using correlation analysis and variance inflation factor (VIF). Values of VIF less than 10 indicate absence of serious levels of multicollinearity. The model was also checked for presence of heteroscedasticity using Breusch-Pagan/Cook-Weisberg test.

3. Methodology

Data and sampling procedure

Econometric Model : Count Outcome Regression models

Generally farmer adoption decision of a technology or an agricultural practice is modelled as a binary variable which takes the value of 1 for adopters and 0, for non-adopters using logit or probit models. However, in analyzing the level or intensity of adoption of a given technology percentages and share of area have been used in some studies but the challenge in such approaches is in establishing the cutoff points.

It is also known that adoption of farmers in developing countries often happen sequentially and to address this scenario, count regression models are proposed, where adoption equals *0, 1, 2,…n*, where *n* represents the largest number of technologies adopted (Rojas et al., 2012). In this paper, a Poisson regression model and Binomial Regression model members of the family of count regressions are used to examine the number of improved modern bee hives a farmer has adopted.

Given that the utility the farmer derives from the adoption of a number of improved bee hives depend on W, a vector of socio-economic and institutional factors, the utility (U) to farmer *i* as a result of adopting a number of j modern bee hives can be represented as:

$$U_{ji} = \gamma_j (W_i) + \varepsilon_{ji} \quad j = 0, 1, 2,\dots, n \qquad (1)$$

Where *j* is a non-negative integer that represents the number of modern bee hives adopted by the *ith* farmer, γ is a vector of parameters to be estimated, and ε_{ji} is the error term. The *ith* farmer adopts (*j* = 1 or higher) when $U_{ji} > U_{oi}$. Given a dependent variable, Yi the number of modern bee hives adopted by the farmer it can be expressed as:

$$\text{Prob}(Y_i = j) = \frac{e^{-\lambda_i}\lambda^{ji}}{j!}, \quad j = 0, 1, 2\dots, m; \quad i = 1, 2, \dots n \qquad (2)$$

Where j shows the number of bee hives adopted by farmer I, λ_i is both the conditional mean and the variance of the Poisson distribution, and m is the maximum number of modern bee hives adopted. The equality of the mean and the variance distinguishes the Poisson model from other count regression models. The choice of the count data model to use was determined by the meeting or not the condition of equi-dispersion assumed in the Poisson model. Equi-dispersion refer to mean being equal to variance, if mean is below variance we have under-dispersion and if it is greater than variance we have over-dispersion. In case of over-dispersion and under-dispersion the appropriate model to use is the Negative Binomial Model (Kim et al., 2005).

The dependent variable in the Poisson model was the number of improved bee hives adopted by the sample beekeeping household. The farmer were asked about how many improved beehives (Top-bar type) they owned during 2017/19 farming season. The response formed the basis for the construction of the dependent variable. Intensity of adoption of modern beehive was analysed using the Poisson Model and the Negative binomial regression model. A diagnostic test conducted revealed that a negative binomial regression model is suitable for application in this study.

4. Results And Discussion

4.1 Socio-economic characteristics of respondents

The summary statistics of socio-economic variables of the sample are given in Table 1.

Table1. *Summary statistics of socio-economic variables*

Variable and definition	Mean	Std. Dev.	Min	Max
Top-bar hives adopted	0.79	2.77	0	20
Sex (1=male, 0=female)	0.83	0.38	0	1
Age (years)	52.51	13.40	27	90
Education (1= none, 2=primary, 3=secondary, 4=tertiary)	2.39	0.77	1	4
Household size (persons)	6.15	2.44	1	15
Experience in beekeeping (years)	8.47	5.95	1	30
Farm size (hectares)	17.3	21.3	1.5	100
Cultivated area (hectares)	6.30	14.34	0.5	100
Has Off-farm income (1=yes, 0=Otherwise)	0.77	0.43	0	1
Farmer has Training in beekeeping (1=yes, 0=No)	0.41	0.49	0	1
Membership to farmer group (1=yes, 0=no)	0.18	0.39	0	1
Extension access (1=yes, 0=no)	0.27	0.45	0	1
Number of traditional (local) hives used	8.14	6.89	0	37

The sample comprised of 83% male farmers and 17% female farmers. This indicates that beekeeping is dominantly a male activity. The average age of the beekeeping farmers was 52.5 years with 8.5 years of experience in beekeeping. Regarding education, majority of the sample famers have on average attained primary education. Despite the large average farm size of 17.3 hectares, with a range of 1 to 100 hectares, the average cultivated area is smaller at 6.3 hectares. This indicates that beekeeping was done on both small-scale and medium-scale farms in the study area. Most of the beekeeping households (77%) were involved in some form of off-farm income generating activity for example petty trading. This helps to supplement income from crop and livestock farming.

It was, further, found that 41% of the sample farmers have had some training in beekeeping and 18% of the farmers were members of some farmer group or association. In the Zambian agricultural sector it is mandatory for farmers to belong to farmer cooperatives in order to access farmer input support from government. Farmer groups are also used by extension service in delivering their messages to farmers. In this study it was found that 27% of beekeeping farmers reported to have some access to agricultural extension agents in the study area. The results implied that there was low involvement in farmer groups and low access to extension services among the sample farmers. This suggested that there could slow transfer of information and improved beekeeping technologies through extension to farmers in the area. This could result in low adoption of improved technology in particular the Top-bar hive.

4.2 Adoption levels of improved modern bee hive

The Top-bar bee hive is an improved hive compared to the traditional or local hive, it is important for achieving sustainable higher honey yield. The study identified the number of Top-bar hives owned and used by the targeted beekeeping households. The dependent variable was then modelled around the number of Top-bar hives adopted by the farmers. The intensity of adoption of the Top-bar hives is presented in Table 2.

Table2. *Intensity of adoption of Top-bar hives*

Number of Top-bar hives adopted	Frequency	Percent
0	85	86.7
1	3	3.1
2	2	2.0
3	1	1.0
5	1	1.0
6	1	1.0
8	1	1.0
9	2	2.0
10	1	1.0
20	1	1.0

Mean adoption	0.79	
Variance	7.67	

The results in Table 2, show that 86.7% of farmers did not adopt the improved Top-bar as indicated by the zero count recorded, whereas the rest adopted between 1 and 20 Top-bar hives. The mean number of Top-bar hives adopted was about 0.77, with a variance of 7.67.

Since the mean number of Top-bar hives adopted was less than the variance, it implied that there was over-dispersion and as such the Poisson model which assumes equi-dispersion could not be used for analysis. To deal with over-dispersion, the negative binomial regression model has been suggested as appropriate (Kim, et al., 2005) and hence it was used for analysis of adoption intensity.

4.3 Factors determining intensity of adoption of improved bee hive technology

In Table 3 the results of the factors that influence the adoption intensity of improved bee hive technology are presented. Model diagnostic tests were performed to identify the appropriate functional model to use. The parametric estimates across the three models show some similarities in a number variables. A few diagnostics performed indicated presence of many zero counts (over-dispersion). A goodness of fit test based on the log-likelihood value was used to compare the count data models, i.e. Generalized Poisson, Standard Poisson and Negative Binomial Regression model.

The LL values indicate that the generalized Poisson and Negative binomial models have larger values than the Standard Poisson model. In addition the two models have smaller values of the Akaike Information Criterion compared to the Standard Poisson model. The estimated dispersion parameter (alpha) from both the Negative Binomial and the Generalized Poisson model is positive and significant, and which confirms presence of over-dispersion. In this case the appropriate model to use for the estimation is the Negative Binomial. This study, therefore, discusses only the results of the Negative Binomial model due to its significant statistical tests.

Out of 11 variables estimated with the negative binomial regression model, five variables are statistically significant in explaining the intensity of adoption of improved Top-bar technology. Education level of respondents, household size, training in beekeeping, extension contact are statistically significant and positively influence the number of improved hives adopted by the farmers in the study area as shown in Table 3.

Table3. *Factors that influence the adoption intensity of improved bee hive*

Model	Standard Poisson		Generalized Poisson		Negative Binomial	
Variables	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Constant	-2.023	2.242	-1.101	3.024	-7.962	5.266
Sex	0.778	0.668	-0.412	1.020	-0.429	1.272
Age	-0.042*	0.023	-0.039	0.037	-0.069	0.045
Education	0.127	0.370	0.323	0.656	1.243*	0.758
Household size	0.181***	0.055	0.050	0.113	0.503**	0.230
Farm size	0.006***	0.001	0.004**	0.002	0.003	0.003
Has off farm income	0.645	0.517	0.181	0.717	0.937	1.067
Experience in Beekeeping	0.091**	0.046	0.111*	0.060	0.166	0.104
Training Beekeeping	1.027*	0.544	0.873	0.959	2.724**	1.261
Membership	1.573**	0.711	2.004**	0.949	1.950	1.281
Extension access	0.688*	0.418	0.685	0.737	2.073*	1.184
Local hives	-0.413***	0.082	-0.348***	0.121	-0.294**	0.137
Alpha	NA		NA			
LR Chi^2 (11)	275.2		49.79		41.4	
Prob> Chi^2	0.000		0.000		0.000	
Pseudo R^2	0.7014		0.3516		0.2993	
Log likelihood	-58.576		-45.913		-48.458	
AIC	141.15		117.82		122.91	

BIC	171.15		150.32		155.41	
Dispersion	NA		0.4729		NA	
Alpha	-		-		2.485	
Likelihood-ratio test of delta=0: chi^2(1) = 25.33 Prob>=chi^2 = 0.0000						
Note: *, ** and *** indicate significance at 10%, 5% and 1% level s respectively. Source: Computed from field data, 2018						

The results in Table 3 reveal that as farmer's education level increases, their understanding of the benefits of applying improved technologies in honey production improves. The positive and significant coefficient on level of education imply that adoption of improved hives is directly related to the level of education, suggesting that farmers with higher levels of education adopt more improved hives compared to farmers with lower education. This finding is consistent with Deressa et al. (2009) study that found education as important for farmers' adaptation to climate smart agricultural (CSA) practices.

Household size has positive and significant relationship with adoption intensity of the improved hive. This imply that farmers with large households adopt more improved hives compared to farmers with smaller households. Increase in household size make farmers to adopt more improved agricultural technologies because they have more family labour to perform the farm activities. Similar result was found by Mmbando et al. (2021) in Uganda that households with more members have higher intensity of adopting improved technologies in mung bean production. Also Musaba et al. (2022) found a similar result in Zambia and among adopters of improved rice varieties.

Access to extension services increased the intensity of adopting improved hive technology in the study area. This result is consistent with the findings by Asfaw et al. (2016) in Niger, Mmbando et al. (2021) in , which suggest that farmers' contact with extension agents is expected to have positive effect on adoption of technologies.

Training in beekeeping techniques often offered to farmers by non-government organizations on promoting beekeeping as a livelihood strategy, creates awareness and improves knowledge about the new techniques and benefits of adopting such technologies. The results show a positive and significant effect of training on intensity of adopting the improved hive. This suggests that farmers with training in beekeeping have a higher intensity of adopting improved hives compared to farmers with no training in beekeeping. This complements the finding of the intensity of the positive effect of extension contact on intensity of adopting improved hive technology. This result is consistent with Kuboja et al. (2021) in Tanzania and Tarekegn and Ayele (2020) in Ethiopia who found training to improve honey production.

The number of local or traditional hives owned is significant and negatively influence the intensity of adoption of improved hives. This implies that an increase in the number of local hives a farmer owns causes a decrease in the intensity of adopting improved hive technology. This suggests that farmers who have heavily invested in the local hives would be reluctant to replace them with improved modern hives. This is despite the fact that modern hive yield higher quantities and better quality of honey than traditional hives. This preference for local hives is due to low availability of improved hives and financial or credit barriers. This result is consistent with Bekuma (2018) who found low use of improved beehives in Ethiopia.

5. Conclusion

The negative binomial regression results revealed that household size, farmer's education level, training in beekeeping, and extension contact are statistically significant and positively influence the number of improved hives adopted by the farmers in the study area. Whereas, the number of traditional hives owned has negative effect on intensity of adoption of improve hive technology. The study suggests that policy interventions that aim at improving access to extension, beekeeping training programs, education and access to improved hive technology are crucial to enhancing intensity of technology adoption among smallholder farmers.

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