

International Journal of Development and Sustainability
ISSN: 2186-8662 – www.isdsnet.com/ijds
Volume 15 Number 4 (2026): Pages 548-568
https://doi.org/10.63212/IJDS25091001

Factors influencing formal market commercialisation decisions and intensity among small-scale beekeepers in the Eastern Cape, South Africa: A double hurdle approach

Owetu Zamisa *, Amon Taruvinga

Department of Agricultural Economics, Extension and Agribusiness, University of Fort Hare, Private Bag ×1314, Alice, 5700, South Africa

Received: 10 September 2025 | Revised: 11 January 2026 | Accepted: 26 January 2026 | Published: 23 August 2026

Abstract

The study aimed to understand the factors influencing formal Honey market participation and commercialisation intensity among small-scale Beekeepers in Eastern Cape, South Africa. This research was conducted against a background of low participation in honey formal markets by small-scale beekeepers. A cross-sectional survey of 100 small-scale beekeepers was conducted, with respondents randomly selected from a compiled list of active beekeepers in the study area. Analytical methods included descriptive statistics and the Cragg double hurdle model to estimate the decision to participate in formal markets and the extent of participation. The descriptive results reveal a commercialisation index of 36% under formal markets and a commercialisation index of 54% under informal markets. The overall commercialisation index for both markets (formal and informal) was 90%. The double hurdle model results revealed that marital status, educational level, number of hives owned, land size, access to market information, cooperative membership, access to extension services, and crop production are significant factors influencing the decision to commercialise. In the second hurdle, age, beekeeping experience, and cooperative membership were found to significantly influence the intensity of commercialisation. The findings emphasise the need for integrated policy interventions that strengthen institutional support, improve market access, and promote beekeeper organisation through cooperatives. Addressing these structural and socio-economic barriers can enhance commercialisation outcomes, thereby improving livelihoods and contributing to the sustainable development of the apiculture sector in the rural areas of South Africa.

Keywords: Beekeepers; Commercialisation; Cragg Double Hurdle; Market

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Cite this article as: Zamisa, O. and Taruvinga, A. (2026), "Factors influencing formal market commercialisation decisions and intensity among small-scale beekeepers in the Eastern Cape, South Africa: A double hurdle approach", *International Journal of Development and Sustainability*, Vol. 15 No. 4, pp. 548-568.

* Corresponding author. *E-mail address:* Owethuzamisa.oz@gmail.com

1. Introduction

Beekeeping, or apiculture, is the practice of keeping honeybees to produce and collect bee-related products like honey, beeswax, and propolis (Guyo and Solomon, 2015; Tutuba et al. 2019). It contributes to food production through honey and brood, supplies raw materials for industries such as candle-making, cosmetics, and textiles, and provides medicinal products (Malisa and Yanda, 2016). As such, beekeeping plays an important role in agriculture, rural development, and national economic growth by enhancing household income and food security (Amulen et al., 2019). In South Africa, the Eastern Cape Province offers favourable conditions for beekeeping due to its diverse agro-ecological zones ranging from coastal thickets to inland grasslands which influence nectar availability and seasonal hive productivity (Forbanka et al., 2025). Districts such as OR Tambo and Amathole are rich in vegetation suitable for beekeeping, including species such as Eucalyptus, Acacia karroo, and indigenous forest flora, which provide vital forage for bees. Socially and economically, the province remains one of South Africa's most impoverished, with over 70% of its population residing in rural areas and facing high unemployment rates [Statistics South Africa (Stats SA, 2024)]. This emphasises the need for sustainable livelihood alternatives like beekeeping, particularly for smallholder household's dependent on mixed farming and natural resource utilisation.

While global studies document ecological and production challenges in beekeeping, the Eastern Cape Province presents a unique context. The Eastern Cape is characterised by fragmented landholdings, weak market infrastructure, and limited agro-processing capacity (Stats SA, 2024). Beekeeping in this province is predominantly small-scale and livelihood-oriented, often practised in remote areas with limited access to formal buyers. The Mpumakoloni Bee Association noted that there are fewer than 150 active small-scale beekeepers in the Eastern Cape Province (Mpumakoloni Bee Association, 2024). The total number of beehives managed by farmers in the Eastern Cape per district municipality is 2 746 with beehive colonies of 2 033 and the highest number of colonies being in Amathole district with 1 463 colonies followed by OR Tambo district with 321 colonies (Peter, 2015). From these colonies the yield is estimated at 19 123 kg in the province (Peter, 2015). Furthermore, many of these beekeepers use a mix of traditional, top-bar and Langstroth hives, often sponsored by government and NGOs (Hans et al. 2018; Yusuf et al. 2018). However, these hive types present significant challenges, for example traditional hives often produce impure or smoky honey, which negatively impacts product quality, marketability, and pricing, thus limiting income potential and hindering value addition opportunities (Tutuba and Vanhaverbeke, 2018). Top-bar hives are generally less efficient, leading to lower honey yields, while Langstroth hives, though more productive, still face issues related to quality control and inadequate infrastructure (Tutuba and Vanhaverbeke, 2018).

Technical expertise is another important factor, the shortage in apiculture extension officers in the province hinders the dissemination of modern hive management techniques, which affects productivity. Studies indicate that over 80% of beekeepers in the province produce fewer than 200 kg of honey annually ranging from 111 kg to 156 kg (Peter, 2015), with few opportunities for high-value markets or value-added products like creamed or infused honey. As a result, most beekeepers in the Eastern Cape operate in the informal sector with limited access to formal markets and less than 10% of beekeepers engage in formal commercialisation, mainly due to the lack of appropriate processing equipment and food-grade facilities (SABIO, 2014). The South African Beekeeping Industry Organisation (SABIO) has acknowledged high dropout rates (50-80%) among small-scale beekeepers, pointing to ineffective post-training support, a lack of mentorship, and fragmented implementation (SABIO, 2014).

Furthermore, beekeeping is a skill-intensive enterprise requiring technical knowledge of hive management, seasonal floral cycles, pest and disease control, and harvesting techniques. Many rural beekeepers in South Africa lack these skills, resulting in poor colony management, low yields, and high losses [Food and Agriculture Organization (FAO, 2021)]. Training programmes are often short-term and theoretical, with little emphasis on hands-on experience or continuous learning. There is also a lack of organised beekeeper associations as a result in many rural settings, beekeepers operate in isolation, with limited opportunities for collaboration, knowledge exchange, or group bargaining [Industrial Development Corporation (IDC, 2016)]; Ricketts and Shackleton, 2020). Lastly, despite growing interest in beekeeping as a rural livelihood strategy, empirical evidence on the determinants of honey commercialisation particularly participation in formal markets remains limited in South Africa. Specifically, the distinction between the decision to participate in formal honey markets and the subsequent intensity of participation is poorly understood. This study

addresses this gap by applying a Cragg double hurdle model, which allows separate estimation of the factors influencing formal market participation and the level of participation among beekeepers.

2. Objectives

The study was guided by the following objectives:

- To estimate the commercialisation status of small-scale beekeepers using descriptive statistics and the Household Commercialisation Index (HCI).
- To estimate the determinants of formal market participation and commercialisation intensity using a Cragg double hurdle model.

3. Materials and methods

3.1. Description of the study area

The research was carried out in four districts (Amathole, Chris Hani, OR Tambo, Joe Gqabi) of the Eastern Cape Province in South Africa as shown in figure 1. The study areas were chosen specifically for their favourable bee foraging environment, including suitable vegetation, temperatures, and water sources (Masehela, 2017; Apraku et al. 2023; World Data, 2024). Salehizadeh et al. (2020) note that honeybees thrive best in temperatures between 20°C and 26°C, and the Eastern Cape has an average temperature range of 20°C to 25°C (World Data, 2024). The districts also have a mix of exotic and native forage plants (Masehela, 2017). Main water sources in the region's villages include boreholes, municipal tankers, community taps/reservoirs, rivers, streams, lakes, dams, and rainwater (Apraku et al., 2023). This makes the study area well-suited for beekeeping. Administrative boundary shapefiles for the province and district municipalities were obtained from official South African spatial data repositories and processed using Geographic Information Systems (GIS) software to generate the study area map.

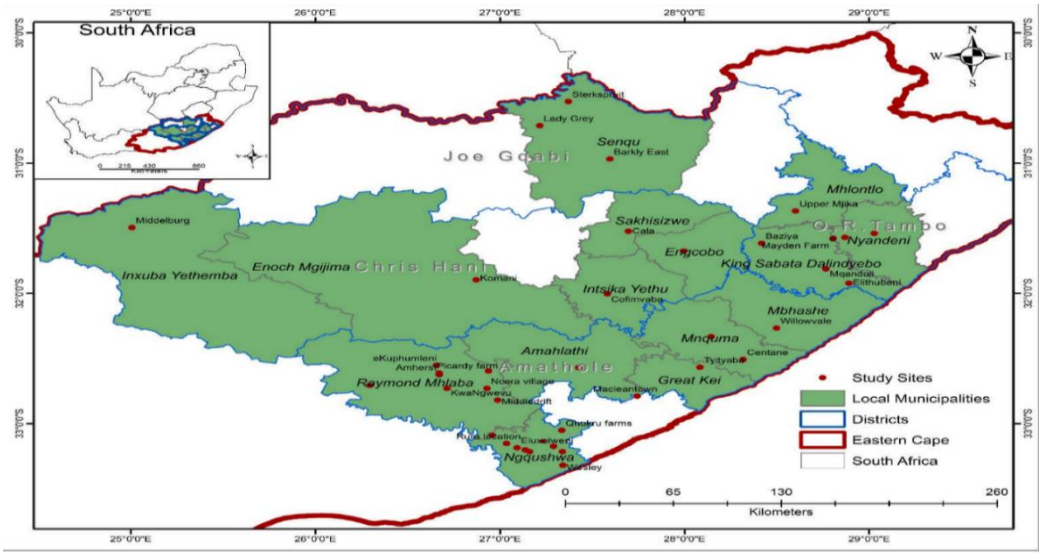


Figure 1. A map showing the study sites (Source: Author's own compilation using GIS, 2023 based on data from Stats SA, 2022)

3.2. Research design and sampling technique

The study used a cross-sectional design and a multi-stage sampling procedure. In the first stage, districts within the Eastern Cape Province were purposively selected based on their known beekeeping activity, ecological suitability for apiculture, and presence of active small-scale beekeepers. Districts with minimal or undocumented beekeeping activity were excluded to ensure relevance to the study objectives. In the second stage, beekeepers within the selected

districts were identified using lists obtained from agricultural extension officers and beekeeper associations operating in the area. These lists were supplemented through snowball referrals, where identified beekeepers referred other active beekeepers in their communities. This process resulted in a total of 118 small-scale beekeepers across the study districts. In the third stage, simple random sampling was applied, and 100 beekeepers were selected for participation in the survey. No communities within the selected districts were excluded once identified as having active beekeepers. The exclusion criterion applied only at the district level, where districts with negligible beekeeping activity were not considered due to the study's focus on active beekeepers.

3.3. Sample size determination

The study was conducted before the precise number of active small-scale beekeepers in province was known. Furthermore, the official numbers of small-scale beekeepers are rarely recorded because they frequently switch between different enterprises. In light of these circumstances, a sample size calculation approach intended for situations with an unknown population size was used in the study. The minimal sample size recommended by Harris (1975) is n ≥ 50 + m, where "m" is the number of predictor factors. VanVoorhis et al. (2007) pointed out that Harris believed the sample should have at least 50 more participants than the number of predictors. Therefore, as indicated by equations (1) and (2), the sample size was calculated using Harris's (1975) formula

$$n \geq 50 + m \quad (1)$$

Where:

n is sample size

m is predictor or independent variables

m = 18, the sample size was therefore estimated as follows:

$$n \geq 50 + 18 = 68 \quad (2)$$

The minimum sample size was therefore 68.

To improve statistical power and account for non-response, the final sample was increased to 100 beekeepers.

3.4. Ethical considerations

Ethical approval for this study was obtained from the University of Fort Hare Research Ethics Committee. Participation was voluntary, and informed consent was obtained from all respondents prior to data collection.

3.5. Theoretical framework

In this study, commercialisation refers specifically to participation in formal honey markets. Formal markets include registered outlets such as supermarkets, retail shops, cafes, processors, and formally contracted buyers. While informal markets include neighbours, community buyers, roadside customers, and mobile traders. Moreover, beekeepers selling exclusively through informal channels were classified as non-commercialised in the participation model. This classification is justified because participation in formal markets reflects a higher level of market integration, requiring compliance with quality standards, volume requirements, and contractual arrangements that differ fundamentally from informal exchange. Treating informal-only sellers as non-participants allows the analysis to focus on factors influencing entry into formal market channels, rather than market participation in general.

The study modelled small-scale beekeepers' commercialisation using a two-stage method (stage 1 decision to commercialise that requires an output commercialisation index larger than 50% and stage 2 the intensity of commercialisation). The double-hurdle model is based on the notion of rational utility maximisation. Small-scale beekeepers are believed to be rational utility maximisation units who determine whether or not to commercialise their products. This decision is assumed to face two hurdles. The first hurdle is whether or not to commercialise and the second hurdle is the level or intensity of commercialisation. These decisions are based on small-scale beekeepers perceived benefits from commercialisation, taking into account socioeconomic and institutional factors (Mudemba et al., 2020). As a re-

sult, the utility associated with each decision is not immediately observable, whereas the commercialisation is observable and unordered, implying that small-scale beekeepers' honey commercialisation might be explained using the utility maximisation theory (Deressa et al., 2008). Therefore, a typical small-scale beekeeper would decide to commercialise, if only if, the perceived benefits of commercialisation exceed those of non-commercialisation (Taruvinga et al., 2021).

4. Econometric analysis

Figure 2 illustrates the conceptual decision framework for small-scale beekeepers' participation and intensity in honey commercialisation, highlighting key socio-economic, technical, and institutional factors.

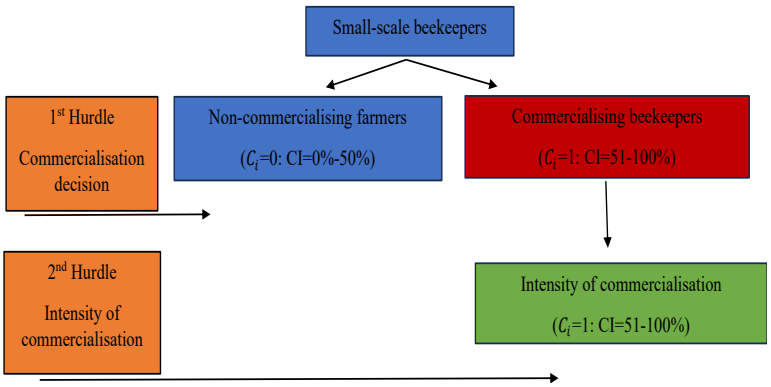


Figure 2. Commercialisation decision framework (Source: Modified from Taruvinga et al., 2021)

The two-stage decision-making process is conceptualised as follows: Small-scale beekeepers determine whether to commercialise based on a commercialisation index over 50% (1st hurdle), which serves as the initial criterion for making this decision. A threshold of 50% of output sold was used to classify beekeepers as commercialised, following established smallholder commercialisation literature, where households selling at least half of their production are considered market-oriented rather than subsistence-oriented (Govereh and Jayne, 2003; Makhura et al. 2001). This threshold is widely applied because it represents a meaningful shift from occasional market participation to systematic engagement with markets. Thus, conditional on the beekeeper's decision regarding commercialisation, small-scale beekeepers determine the degree of commercialisation, represented by a commercialisation index ranging from 51 to 100% (2nd hurdle). The determinants influencing each hurdle are defined as functions of household characteristics (HC) and institutional variables (IV), as shown in equations (3) and (4).

Commercialisation decision (CD) = f (HC, IV) (3)

Intensity of commercialisation (IC) = f (HC, IV) (4)

Where: CD indicates a dichotomous indicator of whether a small-scale beekeeper commercialises or not. Then conditional on the small-scale beekeeper's commercialisation, the IC represents a truncated continuous integer (exceeding 50%) of the percentage ratio of the gross value of honey sales by household *i* in year *b* to the total gross value of all honey produced by the same household in that same year *b*.

4.1. Household commercialisation index

The Household Commercialisation Index was calculated using the gross monetary value of honey sold divided by the total gross value of honey produced. The Household Commercialisation Index (HCI), as applied by Agwu et al. (2013) and Govereh et al. (1999), was utilised to assess the commercialisation level specific to each household as illustrated in equation 5. This index measured the ratio, expressed as a percentage of the gross value of honey sold in formal markets by household i in year b to the total gross value of all honey produced by that same household in the same year (Agwu et al., 2013). This method evaluated honey commercialisation from the output side.

$$\mathrm{HCI}_i = \frac{Gross\ value\ of\ honey\ sold\ in\ formal\ markets\ by\ hh\ i\ in\ year\ b}{Total\ Gross\ value\ of\ all\ honey\ produced\ by\ hh\ i\ in\ year\ b} \times 100 \quad (5)$$

where: HCI_i = Household commercialisation index for household i. Both the numerator and denominator are measured in monetary terms (South African Rand), ensuring that the index reflects value-based rather than quantity-based commercialisation.

4.2. Cragg's double hurdle model

The model was used to identify the drivers of the commercialisation decision and the extent of commercialisation. These two choices are closely related, although they employ different data generating methodologies. The two decisions of the respondent are influenced by two separate stochastic processes, represented by two equations that include the influence of explanatory variables (Cragg, 1971). In this concept, choices are divided into sequential hurdles. Initially, the probit regression model was employed to determine the farmer's decision regarding commercialisation, with an output commercialisation index beyond 50% indicating the decision to commercialise (1), and 50% or below indicating otherwise (0). The second stage involved the estimation of the determinants of the intensity of commercialisation, with a particular emphasis on the output commercialisation index exceeding 50% (51- 100%). Initially, the probit regression model's dependent variable is assigned values of 1 and 0 to represent the decision of whether a small-scale beekeeper decides to commercialise or not in the first stage, as illustrated below. The truncated regression model's dependent variable in the second stage is defined as the intensity of commercialisation among small-scale beekeepers, with values ranging from 51% to 100%.

4.2.1. First hurdle: The participation decision

The first hurdle applied a probit model to assess whether the small-scale beekeeper chooses to commercialise or not. Following Martinez-Espineira (2006) and Abeje et al. (2017), the probit model regression to analyse the commercialisation decision was specified, as illustrated in equation (6):

$$D_i = \ 1 \text{ if } \ D_i^* > 0 \text{ and } \ 0 \text{ if } \ Di^* \leq 0$$
$$D_i^* = \alpha' Z_i + u_i \quad (6)$$

Where: D* is an unobserved participation variable, set to 1 if the respondent engages in commercialisation and 0 if not. Z represents a set of household characteristics, α is a vector of parameters and u_i denotes the error term

4.2.2. Second hurdle: Intensity of commercialisation

Following the approaches by Martinez-Espineira (2006) and Abeje et al. (2017), for the second hurdle, the truncated regression model was employed to analyse factors that influence the level (intensity) of commercialisation, as illustrated in equation (7):

$$\begin{cases} Y_i = \quad Y_i^* \ \text{ if } \ Y_i^* > 0 \text{ and } \ D_i^* > 0 \\ Y_i = \ 0 \ \text{ otherwise} \\ Y_i^* = \beta' X_i + v_i \end{cases} \quad (7)$$

Where: Y_i is the intensification of commercialisation level that depends on latent variable D_i^* being greater than 50% and depending on the commercialisation decision D_i, while β is a vector of parameters, X is a vector of the household characteristics, and v_i is the error term.

If both decisions are made by the individual small-scale beekeeper, the error terms are assumed to be independently and normally distributed as follows: $u_i \sim N(0,1)$ and $v_i \sim N(0, \sigma^2)$.

Up to this point, the log-likelihood functions are presented as the double hurdle model, which combines a univariate probit and a truncated regression model, as shown in equation (8), (Martinez-Espineira, 2006):

$$LogL = \sum ln\left[1 - \Phi(Z_i'\alpha\left(\frac{x_i'\beta}{\sigma}\right)\right] + \sum_+ ln\left[\Phi(Z_i'\alpha)\frac{1}{\sigma}\Phi\left(\frac{y_i - x_i'\beta}{\sigma}\right)\right] \quad (8)$$

Where: Z_i' and x_i' represent independent variables for the probit model and the truncated model, respectively, Φ and ϕ refer to the standard normal probability and density functions respectively, α, σ and β are parameters to be estimated for each model.

Table 1 below presents description of the variables used in the Cragg double hurdle model that was used to estimate the determinants of commercialisation and extent of commercialisation by small scale beekeepers from the study area.

Table 1. Description of the variables used in the Cragg double hurdle

Variable	Description of variables	Type of measurement	Expected sign	
Dependent variables				
Y_1	1st Hurdle - Commercialisation decision	Categorical (1=Commercialise; 0=Otherwise)		
Y_2	2nd Hurdle- Intensity of commercialisation	Continuous		
Independent variables				
			Y_1	Y_2
AGE	Age of respondent	Number (years)	+/-	+/-
GENDER	Gender of respondent	0 = Male, 1 = Female	+	+
EDULEVEL	Educational level of respondent	0 = No formal education; 1= Primary; 2= Secondary; 3 = Tertiary	+	+
MARITALSTATUS	Respondent's marital status	0= single; 1= Married	+	+
EMPLOYMENT	Respondents' status of employment	0 = Unemployed; 1= Employed	+/-	+/-
INCOME	Household income	Number (Rands)	+	+
HHSIZE	Size of household	Number of household members	+/-	+/-
EXPERIENCE	Beekeeping experience	Number (years)	+	+
MARKETDST	Distance to the market	Distance (Kilometres)	-	-
CREDIT	Access to credit	0=No; 1= Yes	+	+
MARKETINFO	Market information access	0=No; 1= Yes	+	+
COOPMEMB	Membership to a cooperative	0=No; 1=Yes	+	+
HIVENO	Beehives owned	Number of hives	+	+

Variable	Description of variables	Type of measurement	Expected sign	
LANDSIZE	Respondents' land ownership	Number of hectares	+	+
EXTENSION	Extension services	0=No; 1= Yes	+	+
TRAINING	Training in beekeeping	0=No; 1= Yes	+	+
LIVESTOCK	Livestock ownership	0=No; 1= Yes	+/-	+/-
CROP	Crop production	0=No; 1= Yes	+	+

4.3. Explanatory variables and prior expectations

The variables that were employed in the Cragg double hurdle model, as illustrated in Table 1, are described in this section.

4.3.1. Dependent variables

- Commercialisation decision: This is a dummy variable indicating whether a beekeeper participates in formal markets (1 = yes, 0 = no).
- Intensity of commercialisation: This is a continuous variable measured as the percentage of honey sold in formal markets relative to total production, using the HCL index (values 51–100%).

4.3.2. Independent variables

- **Age:** Measured in years. Younger household heads may be more entrepreneurial, while older heads may have more experience but greater risk aversion. Age can therefore have either positive or negative effects on commercialisation.
- **Gender:** Dummy (1 = male). Male heads are expected to enhance commercialisation due to greater market engagement.
- **Education:** Categorical; higher education is anticipated to positively influence both participation and intensity through better adoption of market-oriented practices.
- **Household income:** Continuous (Rands); measured as total non-beekeeping income. Higher income is expected to enable input acquisition and production expansion, positively influencing commercialisation.
- **Household size:** Continuous; larger households provide labour but may also allocate more honey for consumption, leading to ambiguous effects.
- **Beekeeping experience:** Continuous (years); more experienced beekeepers are expected to produce and sell more honey.
- **Distance to market:** Continuous (km); measured using respondent estimates and verified with local mapping. Greater distance is expected to reduce commercialisation.
- **Land size:** Continuous (hectares); measured via household reports and field verification. Larger land holdings support higher production and sales.
- **Cooperative membership:** Dummy (1 = member); expected to increase access to markets and information, positively influencing commercialisation.
- **Number of beehives**: Continuous; more hives increase production capacity and market supply.
- **Access to credit:** Dummy; facilitates investment in inputs, positively influencing commercialisation.
- **Access to extension services:** Dummy; supports knowledge and market-oriented practices.
- **Beekeeping training:** Dummy; expected to increase productivity and market engagement.
- **Marital status:** Dummy (1 = married); married household heads may benefit from shared decision-making and pooled resources, which can facilitate commercialisation, but effects may vary depending on household dynamics.

- **Employment status:** Dummy (1 = employed outside farming); employment can provide additional income to invest in beekeeping, but may reduce time available for hive management, leading to ambiguous effects on participation and intensity.
- **Market information:** Dummy (1 = has access to market information); access improves awareness of prices, demand, and buyers, promoting commercialisation, but differences in use or interpretation may lead to variable outcomes.
- **Livestock ownership:** Continuous; livestock can provide complementary income or labour resources for beekeeping, but may also compete for household labour and land, resulting in positive or negative effects on honey commercialisation.
- **Crop production:** Dummy (1 = engages in crop farming); crop activities may complement beekeeping (through pollination and diversified income) or compete for labour and land, leading to ambiguous impacts on commercialisation.

5. Results and discussion

This section presents the results of the study. Initially descriptive results are presented followed by econometrics results.

5.1. The commercialisation status of beekeepers

This section summarises the commercialisation status of beekeepers from the study area. Initially, annual honey production and sales are discussed and lastly, the commercialisation estimates.

5.1.1. Annual honey production and sales estimates from the study area

Table 2 presents the results of the estimated annual honey production and sales for the year 2023. The results indicate that a total of 26 660 kg of honey was produced. Out of the 26 660 kg, most of the honey (23 980 kg) was sold to the market with the remaining honey, 2 680 kg, used for household consumption.

Table 2. Estimated honey production quantities (kilograms)

Annual beekeepers' honey output & sales	**KGs**			
Honey produced per year	26 660			
Market types	**Both formal and informal markets**	**Formal markets**	**Informal markets**	**Not sold**
Honey sold per year	23 980	9 497.5	14 482.5	0
Standard deviation		264.92	257.04	
Honey for consumption				2680

Source: Field survey, 2023

The results further reveal that 10% (2 680kg) of the honey produced was not sold in any market but consumed by the beekeeping households. Honey sold through informal markets comprised of 54% (14 482.5kg), while 36% (9 497.5kg) was sold through formal markets.

5.1.2. Small-scale beekeepers' commercialisation index

Table 3 below shows the results of the estimated small-scale beekeepers' household commercialisation index. The results indicate that the gross value from the sale of 23 980 kg of honey yield at an average price of R41 per kilogram was R983 180 and the gross value of the total honey produced was R1 093 060.

Table 3. Estimated values of honey produced (Rands)

Annual beekeepers' gross value	**Amount (South African Rand)**		
Gross value of total honey produced per year	1 093 060		
Market types	**Both formal and informal markets**	**Formal markets**	**Informal markets**
Gross value of honey sold per year	983 180	389 397.5	593 782.5
Household Commercialisation Index (%)	90	36	54

Source: Field survey, 2023

The commercialisation index was calculated and expressed in terms of the gross value of honey sold on different markets over the gross value of all honey produced by beekeepers during the year 2023. Based on formal market access, the commercialisation index is estimated at 36% while in terms of informal market access, the commercialisation index is estimated at 54%. The overall commercialisation index of beekeepers based on both formal and informal market access is estimated at 90%. Additionally, comparable discoveries were reported by several previous studies (97% by Bhattarai et al. 2020 from Nepal; 97% by Toma et al. 2017 from Ethiopia).

5.2. Type of market used by small-scale beekeepers

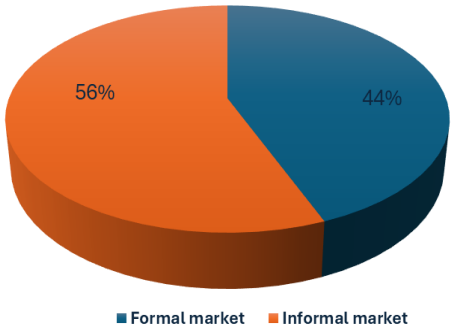


Figure 3. Distribution of market types used by small-scale beekeepers (% of respondents)

The results show the types of markets that the small-scale beekeepers in the research area used to sell their produce. The findings show that a majority of the beekeepers (56%) participated in informal markets, whereas 44% of the beekeepers participated in formal markets (cafes, local shops, and supermarkets). This suggests that informal markets are the most popular markets used by beekeepers. This could be the result of the majority of the study area's beekeepers being isolated from official markets and living in remote areas. Only 35% of households had access to transport, while 65% lacked transport entirely. The average distance to the nearest honey market was 44.6 km (ranging from 5 to 130 km), further increasing transaction costs for remote households. Combined with small hive ownership with the

average number of beehives owned by the beekeepers was 20 hives per beekeeper. These constraints reduce incentives to sell honey formally, reinforcing reliance on informal markets in the Eastern Cape. There are also low quantities produced per beekeeper thus limiting the ability to meet minimum purchase requirements of formal buyers, and limited access to storage facilities and certification making informal outlets more attractive despite potentially lower prices. The study results align with previous research by Hans et al. (2018), which indicated that beekeepers participated mostly in informal markets.

5.3. Factors that influence the decision to commercialise and the level of commercialisation among small-scale beekeepers

This section presents the Cragg double hurdle model results for the determinants of the decision to commercialise and intensity of commercialisation among small-scale beekeepers, as summarised in Table 6. The same set of explanatory variables was included in both the probit and truncated regression equations. The models were estimated using STATA software. Diagnostic checks confirmed acceptable model fit and no multicollinearity concerns. Before estimating the double hurdle model, the study compared the Tobit and double hurdle models using statistical measures such as the Akaike Information Criterion (AIC), LR statistical and chi-square test values. A likelihood ratio test was conducted to validate the model by examining the separability of the decision to commercialise and the intensity of commercialisation. If the calculated LR value exceeds the χ^2 critical value, with degrees of freedom equal to the number of independent variables plus the intercept, the Cragg double hurdle model is deemed appropriate (Mal et al. 2012; Danso-Abeam et al. 2019). Alternatively, if the LR value is below this threshold, the Tobit model would provide unbiased and consistent estimates (Mal et al., 2012). The LR test statistics significantly exceeded the χ^2 (18) critical value of 106.55 at the 1% significance level, supporting the double hurdle model, as detailed in Table 5, thereby rejecting the Tobit model. Additionally, the Tobit model's AIC value (529.55) was higher than those of the truncated regression model (281.40) and Probit model (105.37), corroborating the LR test outcome. Consequently, the analysis was structured in two stages: a probit model in the first stage and a truncated regression in the second.

Prior to estimating the double hurdle model, explanatory variables were also examined for multicollinearity using the variance inflation factor (VIF), with all VIF values below ten as shown in table 4. VIF values ranged from 1.12 to 2.94 (mean = 1.58), indicating no multicollinearity concerns. None of the variables approached conventional caution thresholds (VIF ≥ 5), indicating low multicollinearity and robustness of the estimated coefficients.

Table 4. VIF results of variables used in the Cragg double hurdle model

Variables	VIF	1/VIF
Age	1.97	0.509
Gender	1.35	0.739
Marital status	1.39	0.720
Educational level	1.55	0.645
Employment status	2.37	0.422
Household size	1.30	0.768
Household income	2.00	0.501
Beekeeping experience	1.45	0.692
Number of hives	1.57	0.637
Market distance	1.32	0.715
Land size	1.12	0.892

Variables	VIF	1/VIF
Market information	1.86	0.537
Cooperative membership	1.47	0.679
Credit	1.62	0.617
Extension services	1.77	0.566
Beekeeping training	1.25	0.799
Livestock ownership	1.37	0.729
Crop production	1.53	0.655
Mean VIF	1.58	

Table 5 below shows the LR test for the double hurdle (probit and truncated) model compared to the Tobit. The log-likelihood values of the two estimated models show that the LR-test results recommend rejecting the Tobit model. The test statistic Γ surpasses the critical value of the χ^2 distribution. Separability of participation and intensity decisions is theoretically reasonable because entering formal markets requires meeting institutional and quality requirements, while intensity depends on production capacity and market access. This distinction is supported by the LR test results.

Table 5. Test of double hurdle versus Tobit model

Indicator	Probit	Tobit, (0≤y≤1)	Truncated Regression, (y>0)
LOG-L	-33.68	-244.77	-120.70
Number of observations(N)	100	100	44
Double hurdle versus Tobit test statistic: Γ= 180.78 > χ^2 0.00,18 =106.55			

Source: Model Log-L calculations

Table 6. Results of the Cragg double hurdle estimation

Independent variables	Independent double hurdle model		
	1st hurdle (Dep variable: Commercialisation decision)		2nd hurdle (Dep variable: Intensity of commercialisation)
	Probit regression	Marginal effects	Truncated regression
Age	-0.047 (0.101)	-0.008 (0.082)	0.171 (0.025) **
Gender	0.789 (0.143)	0.148 (0.129)	3.064 (0.112)
Marital status	1.770 (0.012) **	0.331 (0.004)	-2.711 (0.138)
Educational level	0.702(0.056) *	0.132 (0.042)	-0.983 (0.455)

Independent variables	Independent double hurdle model		
	1st hurdle (Dep variable: Commercialisation decision)		2nd hurdle (Dep variable: Intensity of commercialisation)
	Probit regression	Marginal effects	Truncated regression
Employment status	-0.314 (0.628)	-0.059 (0.626)	0.836 (0.681)
Household size	0.070 (0.552)	0.013 (0.550)	0.122 (0.776)
Household income	-0.000 (0.229)	-0.000 (0.218)	-0.000 (0.557)
Beekeeping experience	0.059 (0.229)	0.011 (0.218)	-0.610 (0.000) ***
Number of hives	0.031 (0.002) ***	0.006 (0.000)	0.000 (0.985)
Market distance	-0.003 (0.606)	-0.001 (0.604)	-0.018 (0.522)
Land size	0.190 (0.014) **	0.036 (0.005)	-0.185 (0.338)
Market information	1.467 (0.064) *	0.275 (0.048)	3.7040(0.351)
Cooperative membership	1.668 (0.024) **	0.313 (0.014)	4.274 (0.077) *
Credit	-0.357 (0.499)	-0.070 (0.497)	1.210 (0.454)
Extension services	-2.021 (0.010) **	-0.379 (0.003)	-3.970 (0.232)
Beekeeping training	0.500 (0.402)	0.094 (0.396)	-0.963 (0.774)
Livestock ownership	-0.287 (0.620)	-0.054 (0.618)	-1.585 (0.392)
Crop production	-1.598 (0.024) **	-0.299 (0.011)	-2.813 (0.392)
_cons	-2.949 (0.158)	-	45.801 (0.000) ***
Sigma	-	-	3.759 (0.000) ***
$Pseudo\ R^2$ = 0.51 LR Chi² (18) = 69.82 Prob > Chi² = 0.0000 No. of observations = 100			Wald Chi² (18) = 57.40 Prob > Chi² = 0.0000 No. of observations = 44 Lower limit=51 Upper limit = 100

*Notes: * = p<0.1; ** = p<0.05; *** = p<0.01: p-values in parentheses (Source: Computed from field survey, 2023)*

Table 6 presents the results of the Cragg double hurdle model. The first stage reports the probit estimates, which capture the decision to commercialise. The second stage reports the truncated regression estimates, which explain the intensity of commercialisation among those who have chosen to commercialise.

5.3.1. Drivers of the decision to commercialise among small-scale beekeepers

Factors that influence the decision to commercialise [commercialise (sell honey in formal markets) = 1 vs non-commercialise (do not sell honey in formal markets) = 0] among small-scale beekeepers are discussed in this section. The model results revealed that the variables that drive the decision of small-scale beekeepers to commercialise are marital status, educational level, number of hives, land size, market information, cooperative membership, extension services, and crop production.

5.3.1.1. Marital status

The findings reveal that the marital status of a beekeeper positively influences the decision to commercialise. The marginal effects estimation reveals that a unit change from being single to married would increase the probability of commercialising by 33.1%, holding other variables constant. This indicates that married beekeepers have a higher likelihood of commercialising than their counterparts (single). This increases the marketable surplus by reflecting a broader human resource base for decision-making and labour in beekeeping households. Married rural agricultural households are frequently seeking means to increase food availability and generate income in order to support their families (Mutenje *et al.,* 2016).

5.3.1.2. Educational level

The educational level of a beekeeper has been associated positively with the likelihood to commercialise. The marginal effects estimate that a unit increase in the level of education by household head would increase the probability of commercialisation by 13.2%, holding other independent variables constant. This implies that educated beekeepers have a higher likelihood of selling their honey in formal markets. This could be because education enhances the beekeeper's capacity to obtain new ideas regarding production and market information, thus increases productivity and, as a result, increases formal market participation. This can be largely attributed to the fact that education enables farmers to identify formal market opportunities and make informed decisions. This was also confirmed by Giziew and Admas (2021) who discovered that the household head's education was positively correlated with the probability of participating in honey markets.

5.3.1.3. Number of hives owned

The results show that number of hives owned by a beekeeper influences the decision to commercialise positively. The marginal effects result show that a unit increase in the number of hives owned by a beekeeper would increase the probability of the decision to commercialise by 0.6%, *ceteris paribus*. This means that beekeepers with more hives are more likely to decide to sell their honey in formal markets. This is due to the fact that producers who have a greater number of beehives are able to harvest a greater quantity of honey, resulting in a more marketable surplus. This places them in a position to negotiate more favourable prices and contracts with big clients. These results are in line with the research by Giziew and Admas (2021) that found number of hives to positively influence beekeepers' likelihood to participate in honey markets.

5.3.1.4. Land size

The model results reveal that land size influences the decision to commercialise positively. The marginal effects estimate that a unit increase of land owned by a beekeeper would increase the probability of commercialising by 3.6%, *ceteris paribus*. This indicates that beekeepers with more land are more likely to sell their honey in formal markets. This is because farmers' adoption behaviour is influenced by land ownership, as it is an important unit for agricultural activities. Therefore, beekeepers with more land have more space to place hives and to conduct beekeeping practices which may improve productivity and hence, participation in formal honey markets. This is supported by a study of Giziew and Admas (2021) that reported land size of a household head is positively related to honey sold in the market.

5.3.1.5. Access to market information

The model results reveal that access to market information influences the decision to commercialise positively. The marginal effects results indicate that a unit increase of market information access by a beekeeper would increase the probability of commercialising by 27.5%, *ceteris paribus*. This indicates that beekeepers with more access to market information are more likely to sell their honey in formal markets. The availability of market information that farmers have access to improves their decision to participate in the market since it will encourage them to plan ahead efficiently and produce in response to market demand, which in turn leads to the decision to increase the commercialisation of honey. Due to easier access to markets, beekeepers are more likely to sell their honey at a good price, which leads to increased commercialisation. This is also supported by Kiptoo and Machio (2023) who found market information to positively influence commercialisation of honey.

5.3.1.6. Cooperative membership

Cooperative membership was found to positively influence the commercalisation decision of beekeepers. The marginal effects results show that a unit change from being a non-cooperative member to being a cooperative member would increase the probability of commercialising by 31.3%, *ceteris paribus*. This indicates that beekeepers who are cooperative members are more likely to sell honey in formal markets than their counterparts. This might be the case due to the fact that membership in cooperative groups facilitates the sharing of information about markets, prices, and farming technologies and their benefits. In addition to achieving official market quotas, members of farmer groups are better able to combine their resources and benefit from economies of scale. In the study area, cooperatives facilitate collective input procurement, honey aggregation, basic quality control, and dissemination of market information and strengthening members' bargaining power.

5.3.1.7. Access to extension services

The findings reveal that access to extension services negatively influences the commercialisation decision of beekeepers. A unit increase in extension service access decreases the probability of commercialisation by 37.9%, holding other independent variables constant based on marginal effects results. This means that beekeepers with access to extension services are more likely not to sell their honey in formal markets. Information available in extension services influences commercialisation behaviour of beekeepers. One possible explanation is that extension services in the study area may place greater emphasis on production support than on market linkage development, which could indirectly encourage informal market participation. Furthermore, extension officers may disproportionately work with newer or less commercialised beekeepers who have not yet established relationships with formal buyers.

5.3.1.8. Crop production

The model results show that crop production negatively influences the decision to commercialise among small-scale beekeepers. The marginal effects results indicate that a unit increase in crop production would decrease the probability of commercialising by 29.9%, holding other independent variables constant. This indicates that beekeepers engaging in crop production are less likely to sell their honey in formal markets. This may be because crop production can also be used to mitigate financial constraints, therefore, the income they receive from crop production and the ability to satisfy their needs reduces the probability to participate in formal honey markets. Moreover, the use of lethal pesticides in crop production where integrated pest management is not practised may be detrimental to bees' health, leading to less honey production thus less marketable surplus of honey. Pesticide use in smallholder systems has been shown to reduce honeybee survival and productivity, discouraging beekeeping participation and commercialisation. In the Eastern Cape, weak regulation and limited training amplify these risks, outweighing potential pollination benefits (Mullin et al. 2010; Henry et al. 2012).

5.3.2. Drivers of intensity of commercialisation among small-scale beekeepers

Factors that influence the decision to intensify commercialisation among small-scale beekeepers are discussed in this section. The model revealed that the variables that influence the intensity of commercialisation by small-scale beekeepers are age, beekeeping experience and cooperative membership. Intensity of commercialisation was measured by ratio of quantity of honey produced to honey sold in formal markets by small-scale beekeepers.

5.3.2.1. Age

Model results show a positive association between the beekeeper's age and intensity of honey commercialisation in formal markets. This indicates that older beekeepers are more likely to intensify their sale of honey in formal markets than young beekeepers. This could be because older farmers may have more knowledge in honey production methods, bee management and have a marketing network that enables them to engage in formal markets and thus are able to intensify commercialisation in formal markets. This in line with research by Okpokiri et al. (2015) in Nigeria who also found age of the honey producers to be significant and positively related to the quantity of honey produced and sold because honey production in the study area was practised more by aged men and women.

5.3.2.2. Beekeeping experience

The results show that beekeeping experience negatively influences intensity of honey commercialisation in formal markets. This means that an increase in years of experience in beekeeping decreases the likelihood of beekeepers selling large quantities of their produce in formal markets. Experienced beekeepers may be older and less inclined to expand operations due to risk aversion, which may explain the negative effect of experience on commercialisation intensity. As the farmer becomes more experienced, they will have a higher knowledge to identify challenges, opportunities, and coping mechanisms. They tend to diversify and focus on other agricultural activities such as crop or livestock production rather than just beekeeping activities. These findings are supported by Yuya (2022) and Tadesse et al. (2021) who reported that an increase in experience will decrease honey output sold. The rationale for this is that greater beekeeping experience may correlate with older farmers who are less likely to participate in the honey business and exhibit risk-averse behaviour, leading to reduced adaptability in embracing new technologies that enhance production for marketable surplus (Tadesse et al., 2021).

5.3.2.3. Cooperative membership

The results reveal that cooperative membership influences intensity of honey commercialisation in formal markets positively. This means that beekeepers who are members of cooperatives are more likely to sell large quantities of their honey to formal markets compared to beekeepers who are not a member of a cooperative. Cooperatives normally assist members with technical advice and production inputs which boosts productivity for members. Cooperatives also assist members with formal market access with set quotas which may push members to increase production level to meet set quotas. These findings are supported by Tarekegn et al. (2018) who reported that cooperative membership positively influences quantity of honey sold in the market.

6. Conclusion and recommendations

This study provides new evidence on the factors shaping both participations in honey commercialisation and its intensity among small-scale beekeepers in the Eastern Cape. When viewed against other agricultural subsectors in Southern Africa, beekeeping follows similar commercialisation pathways, shaped by household assets, market access, and institutional support rather than sector-specific factors. Access to market information, collective action, productive assets, and extension services consistently influence participation and intensity, while fragmented value chains, high transaction costs, and limited formal buyers push smallholders toward informal markets. Unlike previous studies, this study integrates socio-economic, technical, and institutional factors within a Cragg double-hurdle framework, revealing how household characteristics, experience, and cooperative membership drive market engagement. The findings highlight that low formal market participation is linked to structural constraints such as fragmented supply chains,

limited storage, and inconsistent buyer presence. Key actionable insights include strengthening cooperatives, improving access to market information and extension services, providing financial support, and addressing socio-economic inequalities. These interventions can reduce barriers, increase formal market participation, and enhance incomes, offering practical guidance for policy and rural development strategies in small-scale beekeeping.

The following policy recommendations are suggested:

Short-term actions

- **Strengthen cooperative participation:** Strengthening cooperative participation can improve market access, bargaining power, and pricing outcomes for small-scale beekeepers. Policy support should focus on incentives for cooperative membership and targeted training to improve cooperative management and collective marketing.
- **Improve access to market information:** Limited access to reliable market information constrains commercial participation. Low-cost platforms such as SMS services, mobile applications, and simplified print materials can improve access to price and demand information, particularly when implemented in partnership with local institutions.
- **Address key socio- economic factors:** Marital status significantly influences ommercialisation decisions, likely due to improved household stability and joint decision-making. Household-based interventions, including joint spousal training, can strengthen production planning and marketing outcomes.
- **Expand access to extension services** Improved access to extension services is critical for commercialisation. Increasing resources for extension and introducing specialised beekeeping support can enhance both technical capacity and market readiness.

Long-term actions

- **Enhance financial and technical capacity:** Financial support mechanisms such as microloans and targeted subsidies can enable hive expansion, land access, and integrated farming systems. These interventions support sustained productivity and commercial engagement.
- **Tailor support by age and experience:** Younger and older beekeepers face different constraints and opportunities. Age-specific programmes can promote innovation among younger beekeepers while encouraging mentorship and knowledge transfer from more experienced producers.

7. Limitations and future research

This study is not without limitations. It is based on a single geographic area, which may limit generalisability, and relies on self-reported production and sales data, which may introduce recall bias. The relatively small number of beekeepers in the second hurdle could also affect the precision of estimates. These limitations should be considered when interpreting the results.

Future research could expand to more diverse geographic areas and use longitudinal or panel data to capture dynamic commercialisation decisions. Larger samples would improve the precision of estimates, particularly for commercialisation intensity. Additional studies could examine value chain dynamics, including buyer relationships, quality standards, and pricing mechanisms, as well as intra-household and gender-related decision-making processes that influence beekeeping commercialisation outcomes.

Funding

The research is funded by the National Research Foundation (NRF – RTF Project) and is gratefully acknowledged.

Data availability statement

Data will be made available on request to the corresponding author.

Acknowledgements

The paper is developed from a PhD thesis in progress from the University of Fort Hare, South Africa 2022-2024. The cooperation of the farmers in the project area is duly acknowledged.

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