Routledge
Taylor & Francis Group

Development Studies Research
An Open Access Journal

ISSN: (Print) 2166-5095 (Online) Journal homepage: https://www.tandfonline.com/loi/rdsr20

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DEVELOPMENT STUDIES RESEARCH, 2017
VOL. 4, NO. 1, 1–8
https://doi.org/10.1080/21665095.2017.1355738

Determinants of economic efficiency among small-scale beekeepers in Tabora and Katavi regions, Tanzania: a stochastic profit frontier approach

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ABSTRACT
This study applied the stochastic profit frontier model to estimate the economic efficiency of small-scale beekeepers in the Tabora and Katavi regions of Tanzania. The results show that the profit of small-scale beekeepers is determined by changes in the cost of labor and materials such as wire and color paint for beehives. Reducing the cost of these can significantly increase profits in beekeeping production. Small-scale beekeepers were found to be economically efficient, with a mean efficiency of 92%. This implies that there is room for improvement by about 8% without changing the profit frontier. Contacts and follow-up by beekeeping extension officers and access to beekeeping training on improved management practices were the main factors that had a significant influence on the economic efficiency of small-scale beekeepers. Thus, the regular and timely provision of extension services and beekeeping training among beekeepers can improve their practices.

ARTICLE HISTORY
Received 7 March 2017
Accepted 10 July 2017

KEYWORDS
Economic efficiency; profit loss; small-scale beekeepers; Tabora and Katavi regions

1. Introduction

The beekeeping sector in Tanzania generates about US$2 million each year from sales of honey and beeswax (MNRT 2010). The sector and its related trades tend to be underestimated both in policy and planning. One reason may be the focus on rural development, in which crop production and livestock rearing are considered dominant income generating activities (Abrol 2014, 2013; Davis et al. 2007; Ellis and Freeman 2004). As a result, the contribution of beekeeping to employment and income generation is generally low. For instance in 2003, the sector contributed only 1% to the GDP (MNRT 2004). According to MNRT (2010) the current contribution of the beekeeping sector to the economy is lower than its potential, which is estimated to be more than 100,000 metric tons of honey and 6600 metric tons of bees wax per annum. There is potential to increase production in this sector as there is a low supply of bee products in Tanzania, especially in the urban areas. In terms of global importance, bee products have been widely used both as food and medicine (Ajibola, Chamunorwa, and Erlwanger 2012; Bogdanov et al. 2008; Castaldo and Capasso 2002). Honey has also become a major ingredient of human foods in Tanzania. The low production of bee products in Tanzania has been attributed to the extensive use and low level of productivity of traditional beehives coupled with other inefficient traditional practices (Husselman, Moeliono, and Paumgarten 2010; Mmasa 2007). Thus, increasing productivity that is normally associated with higher earnings would be an important endeavor for beekeepers in particular and for the national economy at large.

The purpose of this paper is to derive a statistical measure of profit efficiency among small-scale beekeepers in Tanzania using a stochastic profit frontier approach. This analytical approach is used to measure the relative performance of beekeepers by objectively computing a numerical efficiency value and ranking the scores. The analysis shows how close each beekeeper is to the 'best-performers' on the frontier. Such analysis provides information that is useful in assessing the technical efficiency of each beekeeper and relates their score to the socioeconomic variables of beekeepers. Improving efficiency can improve the performance of a farm by distinguishing the 'best-' and 'worst' practices associated with the respective efficiency level. Furthermore, the paper investigates factors that determine the profit efficiency of the beekeepers. Understanding these factors is crucial for the design of policy interventions in the sector. The remainder of this paper is divided into three sections. Section 2 presents the theory of the

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stochastic frontier approach. Section 3 describes the methodology adopted for this study. Section 4 discusses the results followed by the conclusion and policy implications in Section 5.

2. Theoretical framework

Efforts to provide tools for efficiency analysis were pioneered by Knight (1933), Debreu (1951) and Koopmans (1951). Koopmans (1951) provided a definition of technical efficiency while Debreu (1951) introduced the first measure as the 'coefficient of resource utilization'. Following Debreu's (1951) seminal paper, Farrell (1957) provided a definition of frontier production functions as the ability to produce a given level of output at the lowest cost. This definition distinguishes three types of efficiency namely technical efficiency, price or allocative efficiency and economic efficiency, which is the combination of the first two. Technical efficiency refers to the input–output relationship. A firm is said to be technically efficient if it is operating on the production frontier (Ali and Byerlee 1991). Conversely, a firm is said to be technically inefficient if it fails to achieve the maximum output from inputs. It is important to recognize other definitions of technical efficiency as applied to farm/firm. Mbowa (1996) defines an efficient farm as that which utilizes fewer resources than other farms to produce a given quantity of output. Yilma (1996) defines an efficient farm as one which produces more output from the same measurable inputs than others that produce less. Fan (1999) suggests that technical inefficiency is a state in which the actual or observed output from a given input mix is less than the maximum output possible.

Allocative efficiency deals with the extent to which farmers make efficient decisions by using inputs up to the level at which their marginal contribution to production value is equal to the factor cost. According to Rahman (2003), allocative efficiency relates to the degree at which inputs are optimally used, given the observed input prices. These components have been measured using the frontier production function which can be deterministic or stochastic. Deterministic frontier production function requires that all deviations from the frontier are attributed to inefficiency whereas in the stochastic frontier production function it is possible to distinguish between random errors and differences in efficiency. Yotopoulos and Lau (1973) argue that the production function approach to measure efficiency may not be appropriate when farmers face different prices and have different factor endowments. Similarly, Ali and Flinn (1989) argue that the production function framework fails to capture inefficiencies due to differences in factor endowments as well as input and output prices across different farms. As a result, farms may exhibit different 'best practice' production functions and may even operate at different optimal points. This implies that the use of a more flexible profit function model which directly estimates farm-specific efficiency is an ideal approach to account for these differences (Kumbhakar 2001; Ogundari and Ojo 2006; Rahman 2003).

The flexible profit function model combines technical, allocative and scale efficiency measures into one system, thereby resulting into more efficient estimates through simultaneous estimation of the system. Any errors in the production decision are assumed to be translated into lower producers' profits (Ali, Parikh, and Shah 1994). Unlike the production function approach, the profit function model considers the ratio of relative input and output prices that account for allocative efficiency.

Profit functions have been estimated using different functional forms, including the Cobb–Douglas and more flexible functional forms such as the normalized quadratic, normalized translog and the generalized Leontief. It is important to note the main limitation of the translog model is its susceptibility to multicollinearity and potential problems of insufficient degrees of freedom owing to the presence of interaction terms (Ogunniyi 2011). Despite its shortcoming, the translog model has been extensively used to estimate farm efficiency (Hyuha 2006; Nwachukwu and Onyenweaku 2007; Ogunniyi 2011). However, the Cobb–Douglas functional form has been more frequently used to estimate farm efficiency (Ogundari and Ojo 2006; Oladeebo and Oluwaranti 2012) as it is less susceptible to multicollinearity.

In terms of estimation, the stochastic frontier model has often been estimated using two procedures; the two-stage and one-stage procedure. In the two-stage procedure, the predicted efficiency scores are regressed against a number of household and farm characteristics to explain the observed differences in efficiency among farms. However, the procedure has been criticized for being inconsistent with assumptions regarding the independence of the inefficiency effects (Coelli 1996). Thus, the one-stage procedure is often more preferred.

To estimate the stochastic frontier model the inefficiency effects must be defined as a function of the farm-specific factors, and then incorporated directly into the Maximum Likelihood Estimation (MLE) where both the production frontier and the inefficiency effect models are simultaneously estimated as a one-stage process. Battese and Coelli (1995) extended the stochastic production frontier model by estimating it as a linear function of explanatory variables. The advantage of this linear function is that it allows for the estimation of farm-specific efficiency scores and factors explaining differences in efficiency among farmers in a single-stage estimation procedure. The current study adopts the Battese and Coelli (1995) model where a profit function is assumed to be a linear function that can be estimated as a stochastic frontier model.

3. Research methodology

3.1. Study area and sampling

This study was conducted in the Urambo, Kaliua and Sikonge districts in the Tabora region in Tanzania, as well as in Mlele district in the Katavi region. The two regions fall within the miombo ecosystem, which is famous for beekeeping in Tanzania. Since 1999, a number of government agencies, non-government organizations and development projects have intervened in various ways to improve the production of bee products by introducing improved beekeeping technologies. In Sikonge district for example, improved beekeeping technologies such as the use of transitional and commercial beehives were introduced and promoted by the District Council, Tabora Regional Office, Honey King Ltd and the Korea International Cooperation Agency (KOICA). In Urambo district, improved beehives were introduced by the Tanzania Social Action Fund whereas in Mpanda district the Association for Development of Protected Areas Project pioneered the introduction of improved technologies among beekeepers (Hausser and Mpuya 2004).

The four districts were purposively selected based on the predominance of improved beekeeping practices among beekeepers. A total of 198 small-scale beekeepers were selected using a random sampling technique from the sampling frame consisting of 237 beekeepers. This sampling frame was established in collaboration with the district officials before the actual data collection. A structured questionnaire was used to collect primary data from the respondents which included socioeconomic variables such as sex, experience in beekeeping, age, education level, household size, number of beehives owned (both traditional and improved), the size (cubic centimeters) of improved beehives, production levels of various bee products and selling prices. The study also elicited information on the cost of production under improved beekeeping systems.

3.2. Empirical model

The study defines profit efficiency as any gain from operating on the profit frontier, taking into consideration farm-specific prices and factors of production. Farm profit is measured in terms of gross margin which equals the difference between the total revenue and the total variable cost. Mathematically this can be expressed as:

$$\mathrm{GM}(\pi) = \sum \mathrm{TR} - \sum \mathrm{TVC} = \sum P_y Q - \sum P_x X. \quad (1)$$

The modified stochastic Cobb–Douglas profit frontier model with inefficiency effect components was adopted following Battese and Coelli (1995) framework. All parameters in the two models were estimated using the MLE in a single step. The explicit profit efficiency function for small-scale beekeepers in the study area is specified as:

$$\ln \pi_i = \beta_0 + \beta_1 \ln C_{1i} + \beta_2 \ln C_{2i} + \beta_3 \ln C_{3i} + \beta_4 \ln X_{1i} + (v_i - u_i), \quad (2)$$

where π_i = normalized profit for ith beekeepers for $i = 1, 2, 3, \ldots, n$ measured in Tanzanian shillings (TZS) per beehive, C_1 = cost of labor normalized by price of bee products (TZS/beehive), C_2 = cost of transport normalized by price of bee products (TZS/beehive), C_3 = other beekeeping cost normalized by price of bee products (TZS/beehive), X_1 stands for number of improved beehives harvested by the ith beekeeper whereas β_0 and β_j stands for a constant parameter and coefficients of the jth variable for $j = 1, 2, 3, 4$; respectively.

The inefficiency model for estimation is specified as follows:

$$u_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} + \delta_7 Z_{7i} + \delta_8 Z_{8i} + \delta_9 Z_{9i} + \vartheta, \quad (3)$$

where u_i = the inefficiency effects; Z_1 = age of the beekeeper (years); Z_2 = number of household members; Z_3 = sex of the beekeeper (1 = male, 0 = female); Z_4 = number of household members who are fully engaged in beekeeping; Z_5 measures whether one has access to beekeeping extension services (yes= 1, otherwise= 0); Z_6 = number of visits to the beekeeper by the beekeeping extension officer (days per annum); Z_7 measures whether one has subscribed to any beekeeping association (yes = 1, otherwise = 0), Z_8 measures whether one has access to trainings on beekeeping (yes= 1, otherwise= 0), Z_9 = beekeeping experience (number of years), ϑ = error term, δ_0 = a constant term, $\delta_1, \delta_2, \delta_3, \ldots, \delta_9$ = coefficient for zth socioeconomic characteristics of beekeeper, ($z = 1, 2, \ldots, 9$).

Profit loss (PL) due to inefficiency was also calculated. The loss is defined as the amount of profit that is not realized owing to a beekeeper's inefficiency in production given the prices and fixed factor endowments. Such loss is calculated by multiplying the maximum profit by

$(1-PE)$, where PE is the maximum profit per beehive computed by dividing the actual profit per beehive of each beekeepers by his/her efficiency score.

$$PL = \pi_{\max}(1 - PE), \tag{4}$$

where $\pi_{\max}$ = maximum profit of an individual beekeeper (TZS/beehive), PL = profit loss due to inefficiency (TZS/beehive) and PE = profit efficiency.

3.3. Analytical framework

According to Battese and Coelli (1995) the stochastic profit frontier model is therefore defined as:

$$\pi_i = f(P_i, Z_i),\ \exp(\varepsilon_i), \quad \text{where}\ \varepsilon_i = v_i - u_i. \tag{5}$$

Note that $i = 1, 2, 3, \ldots, n$ is the number of beekeepers in the sample; π_i is the normalized profit of the ith beekeeper. The normalized profit is defined as gross revenue minus the variable cost which is then divided by farm-specific output price; P_i is the vector of variable input prices for the ith beekeeper divided by the output price; Z_i is the vector of fixed factor for the ith beekeeper and ε_i is an error term. Note that v_i is assumed to be independently and identically distributed following a normal distribution i.e. iidN(0, σ_v^2) while u_i is a non-negative random variables associated with inefficiency in production. This inefficiency is assumed to be independently distributed with truncation at zero of the normal distribution with mean $\bar{u}_i$ ($\bar{u}_i = \delta_0 + \sum_{d=1}^{j} \delta_{id} W_{id}$) and variance ($\sigma^2 = \sigma_v^2 + \sigma_u^2$). Note that W_i is the jth explanatory variable for $d = 1, 2, 3, \ldots, j$ is associated with inefficiencies of the ith beekeeper while δ_0 and δ_d are unknown parameters to be estimated. The stochastic error term consists of two independent elements (v and u). The element v accounts for random variations in profit attributable to factors beyond the beekeeper's control. A one-sided component $u \geq 0$ reflects economic efficiency relative to the frontier. Thus, when $u = 0$, it implies that farm profit lies on the efficiency frontier (i.e. 100% efficiency) and when $u > 0$, it implies that the farm profit lies below the efficiency frontier. Both v and u are assumed to be independently and normally distributed with zero mean and constant variance. Thus, economic efficiency of an individual beekeeper is derived as the ratio of the observed profit to the corresponding frontier profit given the price of variable inputs and the level of fixed factors of production for a particular beekeeper. Therefore, economic efficiency of the ith beekeeper is defined as:

$$\mathrm{EE}_i = E[\exp(-u_i)/\varepsilon_i] \tag{6}$$

But

$$u_i = \delta_0 + \sum_{d=1}^{j} \delta_d W_d \tag{7}$$

All variables in Equations (6) and (7) are as previously defined. Substituting Equation (7) into Equation (6) yields;

$$\mathrm{EE}_i = E[\exp(-\delta_0 - \sum_{d=1}^{j} \delta_d W_d)/\varepsilon_i \tag{8}$$

where EE_i is the economic efficiency of the ith farm and E is the expectation operator, which is achieved by obtaining the expressions for the conditional expectation of u_i given the observed value of ε_i. The maximum likelihood method is used to estimate the unknown parameters where the stochastic profit frontier and the inefficiency effects functions are estimated simultaneously. The likelihood function is expressed in terms of the variance parameters as: $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \frac{\sigma_u^2}{\sigma^2}$ (Battese and Coelli 1995). The variance (σ^2) is a measure of the overall fit and correctness of the specified distribution of the composite error term while gama (γ) tests whether inefficiency exists.

4. Results and discussion

4.1. Descriptive statistics of variables in the stochastic profit frontier function

Table 1 presents descriptive statistics for different variables used in the stochastic profit frontier model. The

Table 1. Descriptive statistics of variables in the stochastic profit frontier function.

Variable name	Minimum	Maximum	Mean	Std. deviation
Household members full involved in beekeeping	1.00	5.00	1.96	0.96
Total number of improved beehives harvested	1.00	140.00	11.05	18.94
Beekeeping experience (number of years)	2	60	16.27	16.42
Age of the beekeeper (years)	19.00	85.00	49.11	16.11
Others costs (TZS/beehive)	210.00	33,333.33	3495.00	5701.93
Transport costs (TZS/beehive)	333.33	150,000.00	10,137.00	25,068.47
Labor costs (TZS/beehive)	625.00	205,000.00	13,893.00	31,216.79
Actual profit (TZS/beehive)	3800.00	115,000.00	41,451.00	27,960.79

average age of beekeepers' in the study area was about 49 years with a standard deviation of 16 year. This signifies that many of the beekeepers in the study area were in the productive age category. The average number of household members who were fully engaged in beekeeping was approximately one while the average beekeeping experience was approximately 16 years. Moreover, the mean number of improved beehives harvested by each beekeeper in the study area was 11.

Beekeepers in the study area earned about 41,451 TZS/beehive as profit with a standard deviation of 27,960.80 TZS. The mean cost was estimated to be around 13,893 TZS/beehive, 10,137.00 TZS/beehive and 3495.00 TZS/beehive for labor, transport and other inputs and/services, respectively. Both the profit and the cost of production per beehive had small standard deviation indicating that the variation in profit margin and cost of production for most of the small-scale beekeepers in the sample was small (Table 1).

4.2. MLE of the stochastic Cobb–Douglas profit frontier function

The stochastic profit frontier model was tested for its goodness of fit and accuracy of specified distribution assumption of the composite error term and existence of inefficiency among beekeepers. Results presented in Table 2 reveal that the estimated value of gamma (0.95) is close to 1 and was significantly different from zero ($p < .01$) implying the existence of inefficiencies among small-scale beekeepers in the study area. This indicates that 95% of disturbance in the stochastic profit frontier model is due to the economic inefficiency of small-scale beekeepers attributable to their socioeconomic characteristics. The estimated variance (σ^2) at 0.14 was significantly different from zero ($p < .01$) indicating goodness of fit and correct specification of the distribution of the composite error term. The log-likelihood ratio test statistics of the one-sided error was 143.54 and was significant ($p < .05$). Therefore the tests of null hypotheses for the absence of economic inefficiency ($H_0{:}\gamma = \delta_0 = \delta_1 = \ldots = \delta_9 = 0$) and that inefficiency effects are not stochastic ($H_0{:}\gamma = 0$) are all rejected ($p < .01$). The implication of these findings is that the traditional average which would be obtained using the ordinary least squares function is an inadequate representation of the results; and thus an economic inefficiency exist among small-scale beekeepers in the study area.

The MLE of the parameters of the stochastic profit frontier model is presented in Table 2. The results revealed that coefficients for the cost of labor and other materials had a negative sign and both were statistically significant ($p < .001$). A negative sign indicates that any reduction in the cost of these variable inputs would increase the profitability of beekeeping. The estimated function reveals that the cost of transport can potentially lower the profit of beekeepers in the study area. Results show that a unit increase in transport cost can decrease the profit by 2%.

4.3. Determinants of farm-specific economic efficiency

Table 2 also presents the results of factors that explain variation in economic efficiency among small-scale

Table 2. Maximum likelihood estimates of parameters of the Cobb–Douglas stochastic profit frontier function and profit inefficiency for small-scale beekeepers in the study area.

Variables	Expected sign	Coefficients	Standard error	*t*-Ratios
General model				
Constant		2.35	0.02	111.226
Normalized costs of labor (TZS/beehive)	-ve	−0.005***	0.005	−0.96
Normalized costs of transport (TZS/beehive)	-ve	0.02	0.006	2.88
Normalized costs of other materials (TZS/beehive)	-ve	−0.003***	0.005	−0.53
Number of improved beehives harvested	+ve	0.007	0.001	13.22
Inefficiency model				
Constant		−2.57	0.32	−8.03
Age of the beekeeper	+ve/-ve	0.02***	0.01	1.91
Sex of the beekeeper	+ve/-ve	0.32***	0.41	0.79
Number of household member fully engaged in beekeeping	+ve	0.31	0.08	3.78
Number of visits per year by the beekeeping officers	-ve	−0.19***	0.08	−2.48
Membership to beekeeping association	+ve	0.42***	0.23	1.86
Access to beekeeping improved management practices trainings	-ve	−1.13***	0.26	−4.33
Beekeeping experiences (number of years)	+ve/-ve	0.02	0.005	4.37
Diagnostic statistics				
Sigma-square $\sigma^2 = \sigma_v^2 + \sigma_u^2$		0.14***	0.015	9.13
Gama $\gamma = \sigma_u^2/(\sigma_v^2 + \sigma_u^2)$		0.95***	0.01	97.17
LR test of the one-sided error		143.54**		

Source: Computer print-out of FRONTIER 4.1.
Note: ***, **, * implies significance at 0.01, 0.05 and 0.1 probability levels, respectively.

beekeepers in the study area. With reference to the specification of the inefficiency model in Equation (3), a variable with a negative sign coefficient means it is positively related to economic efficiency and vice versa. In this case, the number of contacts with the beekeeping extension officers significantly explained the observed variation in economic efficiency among small-scale beekeepers. This implies the effectiveness of extension services that targeted small-scale beekeepers. This result is contrary to that of Shiferaw and Gebremedhin (2015) who found extension services to have a statistically insignificant effect on the technical efficiency of honey producers in Ethiopia. However, access to beekeeping training on improved management practices was found to significantly explain the variation in economic efficiency among small-scale beekeepers in the study area. This could be related to the advantage of getting technical knowledge and skills related to honey production as a result of training.

Meanwhile, the sex of the beekeeper, membership in beekeeping associations and experience in beekeeping were positively and statistically significant ($p < .01$). This implies their negative influence on economic efficiency. The positive coefficient of the variable on sex implies that male beekeepers are more economically inefficient than female beekeepers. Similar findings were also reported by Oladeebo and Fajuyigbe (2007) among rice farmers in Nigeria whereby female farmers were more efficient than male farmers. However, other studies have revealed that female farmers are as efficient as males in resource utilization (Adesina and Djato 1997; Kinkingninhoun-Mêdagbé et al. 2010; Quisumbing 1996). Findings from the focus group discussion revealed that beekeepers with more experience in beekeeping (years) tend to take less risks, and are less willing to adopt new innovations in order to produce more efficiently than those who are less experienced. The less experienced beekeepers tend to take more risks which in turn expose them to more productive innovations. Moreover, the less experienced beekeepers are also more receptive to new ideas or technologies than their experienced counterparts. The coefficient on the number of contacts with beekeeping extension officers and access to beekeeping training were negative and statistically significant, which indicates a positive influence on economic efficiency. The more contacts a beekeeper has with extension services and the more beekeeping training they receive, the more economically efficient the beekeeper becomes. This finding is in line with that of Olohungbebe and Daniel (2015) who noted that adequate training on the rudiments of beekeeping determined the improvement of resource use efficiency for honey production in Nigeria. The training and extension services the beekeepers receive tends to strengthen beekeepers' technical know-how thereby improving their beekeeping performance. Exposure to training and extension services allows beekeepers to acquire new insights into beekeeping.

4.4. Profit efficiency

The economic efficiency scores show that the majority (82.8%) of small-scale beekeepers have scores greater than 90% relative to the estimated economic efficiency frontier model (Table 3). The maximum economic efficiency score attained was 98% while the minimum was 19%. The mean economic efficiency was 92%, indicating potential for improvement by almost 8% through efficient use of the current technology. In general, most of the small-scale beekeepers are economically efficient.

4.5. PL in beekeeping using improved beehives

The inefficiency score translated into a PL per beehive that ranges from 560.00 TZS to 8271.00 TZS with a mean of 2633.20 TZS per beehive. A large proportion of small-scale beekeepers (34.5%) experiencing this loss was within the '1001–2000' category of PL (Table 4).

Table 3. Economic efficiency scores of beekeepers in the study area.

Economic efficiency scores	Frequency	Percent	Cumulative percent
Less than 70	3	1.5	1.5
$70 \geq 80$	3	1.5	3.0
$81 \geq 90$	28	14.1	17.2
Greater than 90	164	82.8	100.0
Total	198	100.0	
Minimum	19		
Maximum	98		
Mean	92.03		
Standard error	0.689		
Standard deviation	9.701		

Table 4. PL in beekeeping.

Profit loss	Frequency	Percent	Cumulative percent
≤1000	15	8.8	8.8
1001–2000	59	34.5	43.3
2001–3000	45	26.3	69.6
3001–4000	23	13.5	83.0
4001–5000	17	9.9	93.0
5001–6000	3	1.8	94.7
7001–8000	5	2.9	97.7
8001–9000	4	2.3	100.0
Total	171	100.0	
Minimum	560.00		
Maximum	8271.00		
Mean	2633.22		
Standard error	129.842		
Standard deviation	1697.901		

Source: Computed from MLE results.

5. Conclusion and policy implications

This study adopted the stochastic profit frontier model to estimate the economic efficiency of small-scale beekeepers in the Tabora and Katavi regions of Tanzania. The results show that the profit of small-scale beekeepers is highly influenced by changes in the cost of labor and materials required for beehives. Reducing the cost of these inputs can significantly increase profit levels from beekeeping. Thus, interventions to reduce the cost of labor and ease the availability and cost of materials for all essential inputs for beekeeping are ideal means to enhance economic efficiency among small-scale beekeepers. Small-scale beekeepers in the study area had a mean economically efficient of 92%. This implies that there is room for improvement by about 8% without changing the profit frontier.

Visits by beekeeping extension officers and access to beekeeping training are the main factors that significantly enhanced the economic efficiency of small-scale beekeepers. This finding suggests that policies aiming at increasing the number of beekeeping extension officers and training on improved beekeeping management practices are expected to increase beekeepers' efficiency probably due to scale effect. This can be achieved through regular training and the timely provision of extension services among beekeepers. Also it is important to examine existing technological packages and create awareness among beekeepers. Thus, recruitment of beekeeping officers to serve at the village and/or ward level as well as investing in rural infrastructure such as roads would ease the transfer of relevant beekeeping information to flow from centers to the peripheral locations where the majority of beekeepers dwell.

Disclosure statement

No potential conflict of interest was reported by the authors.

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