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Technical efficiency of small-scale honey producer in Ethiopia: A Stochastic Frontier Analysis

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Abstract

Ethiopian farmers have a long tradition of beekeeping and the country has huge potential for honey production. However traditional mode of production still dominate the sub sector which negatively affect the total production and productivity. A number of studies has been conducted to better understand the working honey production however none of them systematically investigate the extent of technical efficiency of the sub-sector. This paper uses Stochastic Frontier production model to quantifying the extent of technical efficiency and identify exogenous determinant of inefficiency. The result showed that consistent with other studies traditional practice dominate small scale honey production in Ethiopia. The finding also revealed that use of purchased inputs such as bee forage and other supplement is very limited among honey producers indicating that natural bee forage is the primary source of bee forage. The immediate consequence of all these is low production and productivity. The number of hives the household owns, whether the household used improved apiculture technologies, availability of natural forest which is the primary sources of nectar for bees and amount of land owned by the households were found to have a significant influence on the amount of honey produced by beekeeper. Our result further showed that the mean technical efficiency of honey producers is 0.79 implying that, on average honey producer produce 80 percent of the maximum output. The implication is that 20 percent of the potential output is lost due to technical inefficiency. Number of hives owned by a honey produces, distance to district town-a proxy to market access, household wealth, and whether the household head has a leadership role in the PA affect the technical efficiency of honey producers. The finding suggest that policies that aim to expand the use of improved hives is expected to increase the honey production at household level. The result also suggest that investment on rural infrastructure would be instrumental in improving technical efficiency of honey producer.

Key word: Small-scale honey producer, Ethiopia, technical efficiency in apiculture, stochastic frontier analysis

JEL Code: Q12. Q10. D13.C31

1. Introduction

Honey production is environmentally friendly practices and suitable for low income households. Particularly for rural households beekeeping can coexist effortless with regular farming activities (Miklyaev, M et.al 2012).

Those engaged in beekeeping could earn income from production and marketing of honey and its by-products (beeswax, royal jelly, pollen, propolis, bee colonies, and bee venom). The sector could also create a non-gender-biased employment opportunities. In addition of being the source of livelihood, due to their biological nature bee populations increase the crop productivity and conserve natural flora, since the insects pollinate crops, flowers and trees in their aerial roaming.

In Ethiopia beekeeping and honey production is ancient tradition that has been incorporated into Ethiopian culture. In fact the country is known for exporting beewax for centuries (Gezahegne, 2001) and still the sector serve as an important source for livelihood for its rural population (Aklilu, 2002).

Ethiopia is among the major producer of honey both in Africa and in the world. For instance in 2013 the country produced about 45 thousand tonnes which accounted about 27% and 3% of African and World honey production respectively and makes the country the largest producers in Africa and the tenth in the world (FAOSTAT, 2015). Recent data indicates that the total volume of honey production is about 49 thousand tonnes (CSA 2015).

The country has huge potential for honey production. Due to the availability of botanically diversified honey source plant species honey produced in Ethiopia has a variety of natural flavors and this gives the country a competitive advantage. In addition Ethiopian honey's also has desirable qualities, such as low moisture content especially in drier areas, and absence of GMO pollen which have been widely recognized in the international market (Gallmann, P., and Thomas, H., 2012). Furthermore demand for honey and the other natural byproducts like wax and royal jelly remains high which further makes the sector more promising to engage in.

Honey is produced in almost all parts of Ethiopia, with distinctive types of honey coming from different regions mainly due to the type of bee forage available in the regions. Irrespective of where it is produced, honey in Ethiopia is primarily produced for market. For instance out of the total honey production, about 56 % is destined to market the remaining portion is used for general consumption at household level (CSA, 2014).

Another feature of honey production in Ethiopia is that other beekeeping products other than honey have been given less attention. Though beewax is an important product of honey production, it production is limited in Ethiopia because preparing and selling small quantities of beeswax rather difficult for small beekeepers (Gallmann, P., and Thomas, H., 2012). Furthermore the fact that it requires sizable capital to accumulate sizable wax for onward bulk sale also make engaging in wax business difficult for small traders (ibdi). As a result it is under produced by small scale producers. Similarly other hives products such as bee pollen, propolis, royal jelly and bee venom are also under produced and the opportunity is under exploited by small holder bee producers in Ethiopia.

Recognizing its potential contribution the government of Ethiopia explicitly mentioned the sector in its medium term growth plan (FDREMOFED, 2010). Furthermore the sector has been incorporated into the working agenda of the Government of Ethiopia, especially the Ethiopian Ministry of Agriculture (MoA), National Research Centers (Holeta, Andasa), and various nongovernmental organizations. To help improve the sector and develop the honey value chain in country the Ethiopian Honey and Beeswax Producers and Exporters Association (EHBPEA) and the Ethiopian Beekeeper's Association (EBA) has also been established.

Despite the long tradition of beekeeping in Ethiopia, being the leading honey producer, the availability of huge potential and the attention given to the sector traditional production system is the main feature where 96% of the hives are reported to be traditional and 91% of the total honey produced come from traditional hives (CSA, 2015). This result in low productivity, which in turn result in lower contribution to the countries agricultural GDP. To increase the productivity of the sector honey producer technical efficiency need to be improved.

Thus there is a need to understand the extent of technical efficiency and identify factors that exert influence on honey producer's performance so as to guide policy makers design and implements effective policy and programs. Though there are studies on the sector (Gebremedhin, B. and Gebremedhin, B., 2014: Gallmann, P., and Thomas, H., 2012: Miklyaev, M et.al 2012: Tessega B., 2009: Melaku Girma, et.al, 2008: Workneh Abebe et.al, 2008: Aklilu, 2002) none of them empirically investigate the extent of technical efficiency and identify factor that are associated with it.

This study therefore has the objectives of quantifying the extent of technical efficiency as well as identify factors that are associated with the estimated farm level inefficiency using a stochastic production function framework. The findings of this study suggest recommendations to improve the production performance of small scale honey producers aiming at improving farm level efficiency and thus increase their productivity.

2. Analytical framework

The paper focus on technical efficiency of small scale honey production in Ethiopia. In economic terms technical efficiency can be thought of as the ability to minimize input use in the production of a given output (Kumbhakar and Lovell, 2000). Thus technical efficiency measures the actual output to the optimal value as specified by a production function. A number of methodologies has been developed to measure efficiency.

Early authors such as Aigner and Chu (1968) and Førsund and Jansen (1977) use a deterministic models that attribute all deviations from the theoretical maximum is attributed solely to the inefficiency of producers. Then linear and quadratic programming methods has been suggested to compute the parameters of such models (Aigner and Chu, 1968). One drawback of this approach is that the results obtained cannot be used for inferential purpose as programming estimators do not produce standard errors for the coefficients Greene (2008).

The above programming approach lay the foundation for the development of data envelopment analysis (DEA) by Charnes, A., et.al (1978) and eventually supplanted by it (Greene, 2008). DEA is a non- parametric and non-stochastic efficiency measurement technique.

DEA constructs a piecewise linear, quasi-convex hull around the data points in the input space. Then based on the constructed, quasi-convex hull, technical efficiency is measured by comparing observed producers with that of observed best practice. The main advantage of DEA is that it does not require assumptions about the form of the technology. However this approach share the same drawback of other deterministic estimators i.e. it attribute deviation of an observation from the frontier to inefficiency.

Motivated by the idea that deviations from the production frontier might not be entirely under the control of the producers being studied a more flexible models called stochastic production frontier was developed notably by Aigner, et.al, (1977) and Meeusen and van den Broeck (1977). Under stochastic production frontier framework it become possible to separately account for factors beyond and within the control of producers such that only the latter will be considered as technical inefficiency, cause inefficiency.

This approach redress the main drawbacks of any deterministic frontier specification where random events such as bad weather as well as any error or imperfection in the specification of the model or measurement of its component variables might ultimately translate into increased inefficiency (Greene, 2008). In addition stochastic production frontier setting allows one to incorporate exogenous variables that exert influences on efficiency. Such analysis shades light on factors that are associated with efficiency differentials among producers which is the main aim of this paper. Therefore, the paper utilize a stochastic production frontier framework to measure technical efficiency and identify factor that explain efficiency differentials among small scale honey producers in Ethiopia.

3. Model specification

To model output-oriented technical efficiency, we start by specifying a generic stochastic production function as follow (Kumbhakar and Lovell, 2000).

$$y_i = f(x_i;\ \beta) * \exp\{v_i\} * TE_i \tag{1}$$

Where; y_i is the scalar output of producer i, i = 1,..., N, x_i is a vector of M inputs used by producer i, β is a vector of technology parameters to be estimated and TE_i is the output-oriented technical efficiency of producer i which provides a measure of the shortfall of observed output from maximum feasible output. $f(x_i;\ \beta)$a deterministic part common to all produces, $\exp\{v_i\}$ producer-specific random shocks, $[f(x_i;\ \beta) * \exp\{v_i\}]$ is a stochastic production frontier.

In the received literature the Cobb-Douglas and translog models are the most widely used specification of the production function (Greene, 2008). In this paper $f(x_i;\ \beta)$ is assumed to have a Cobb-Douglas form and its log linear form is given as

$$\ln y_i = \beta_0 + \sum \beta_n \ln x_{in} + \epsilon_i \tag{2}$$

Where; $\epsilon_i = v_i - u_i$ is the composite error terms; v_i, is the two-sided "noise" component; and u_i is the nonnegative technical inefficiency component. By making distributional assumption on v_i and u_i the model parameters and thus the technical efficiency of each producer will be estimated.

Though different functional forms has been used for v_i and u_i in the application of stochastic production frontier analysis following the work of Aigner et al.(1977) this paper make the following distributional assumption about the error terms in eq (2). i) v_i ~ iid N (0, σ_v^2); ii) u_i ~ iid N^+(0, σ_u^2); that is, as nonnegative half normal; iii) v_i and u_i are distributed independently of each other, and of the regressors. The choice of half normal for u is further justified by the principle of parsimony.

Exogenous determinant of efficiency is introduced into the above models as a function of σ_u^2 (Kumbhakar C. S., et.al, 2015). Formally,

$$\sigma_{u,i}^2 = \exp\left(\mathrm{Z}_i' w_i\right) \tag{3}$$

Where; Z_i' is vector of exogenous variables that influence producer level technical efficiency and w_i, is the corresponding parameters vectors to be estimated. As argued by Kumbhakar C. S., et.al, (2015) specifying exogenous efficiency determinant variables as a function of $\sigma_{u,i}^2$ permit solving two problems at once: correcting for one source of heteroskedasticity and incorporating exogenous influences on efficiency.

The log likelihood function of the stochastic production frontier models that incorporating exogenous determinants of efficiency is thus given as.

$$L_i = -\ln\left(\frac{1}{2}\right) - \frac{1}{2}\ln\left[\sigma_v^2 + \left(\exp\left(\mathrm{Z}_i' w_i\right)\right)\right] + \ln\phi\left(\frac{\epsilon_i}{\sqrt{\sigma_v^2 + \left(\exp\left(\mathrm{Z}_i' w_i\right)\right)}}\right) + \ln\Phi\left(\frac{\mu_{*i}}{\sigma_*}\right) \tag{4}$$

Where; $\mu_{*i} = \frac{-(\exp(Z_i' w_i))\epsilon_i}{\sigma_v^2 + \left(\exp(Z_i' w_i)\right)}$, $\sigma_*^2 = \frac{(\exp(Z_i' w_i))\sigma_v^2}{\sigma_v^2 + \left(\exp(Z_i' w_i)\right)}$.

Stata is used to maximize the log likelihood function and estimate all the parameters. Then the technical efficiency index is computed using the formula given by (Battese and Coelli, 1988).

$$TE_i = \mathrm{E}[\exp(-u_i|\epsilon_i)] = \exp(-\mu_{*i} + \tfrac{1}{2}\sigma_*^2)\frac{\Phi(\frac{\mu_{*i}}{\sigma_*} - \sigma_*^2)}{\Phi(\frac{\mu_{*i}}{\sigma_*})} \tag{5}$$

Where μ_{*i} and σ_* is defined in (4)

4. Empirical model

The analysis of technical efficiency in this study has two components. The first is the estimation of a stochastic production frontier that serves as a benchmark against which to estimate the technical efficiency of honey producers while the second component identifies exogenous factor that are associated with producer's performance in the production of honey.

Following from the aforementioned discussion the empirical model of the production frontier equations is specified as follows.

$$\begin{aligned} lnthon = \beta_0 + \beta_1 lnpinput_i + \beta_2 lnntrdh_i + \beta_3 lnntrnsh_i + \beta_4 lnnmodh_i \\ + \beta_5 lnnforg_i + \beta_6 lnland_i + \beta_{37} modh_i + \beta_8 azzone_{\mathrm{i}} + \epsilon_i \end{aligned} \tag{6}$$

The dependent variable in the production function is the total honey produced by the household during the production season.

Explanatory variables in the production function equation

Bee forage and supplement used (lnpinput)**:** Though not very common small scale honey produces in Ethiopia purchase bee forage seeds and plant then in apiaries as bee forage. Furthermore during dry season thus use sugar and bean flours as feed supplements to bees. It proves to be difficult to estimate the amount of these input in standard units such as kg. Instead the total expenditure on bee forage, supplement and other input is included in the production function. The use of these input is expected to have a positive effect on the amount on honey produced by a household.

Number of hives (Number of traditional hives (lnntrdh), Number of transitional hives (lnntrnsh and Number of modern hives (lnnmodh)**.** Hives are the primary physical inputs needed for honey production. It is expected that number of hives (traditional, transitional and modern) the household own to have a positive effect on the amount of honey produced. Thus in the production function number of traditional, transitional and modern hive the household owned is included.

Forest coverage of the area in hectare (lnnforg)**:** The existence of forest and other vegetation is an important input for honey producers in the country. Thus honey producers that resides in an area where there is large forest coverage has access to ample nectar plants and thus expected to produce more honey.

Land owned by the households (lnland). Land owned by the households is included in the production frontier equations since crops that can serves as the sources of nectar for bees is directly related to amount of land owned by the households. However, if a households with large plot of land is engaged in intensive agriculture they are more likely to use agro-chemicals that are harmful to bees. Thus keeping all other things constant the effect of land ownership on honey production could be either positive or negative.

Use of improved hives (modh)**:** Like any agricultural activity use of improved technology is expected to boost production. To capture the use of improved technology a dummy variable (1 =use improved hive 0= otherwise) is introduced in the production function.

Agro-ecology zone (azzone)**:** The agro-ecology zone of the area where the farmer keep their bee hives is expected to have an effect on the amount of honey produced by the honey producer primary through its effect on the availability of bee forage and water. However the effect of the agro-ecology zone of the area on the amount of honey production is not clear since there are different bee species in the country with different adaptation capacity to different agro-ecological zone (Amssalu et al. 2004). Agro-ecology zone is introduced in the production function as a dummy variable where 1 if for high land areas (above 1500 m asl) and 0 for low land areas (below 1500 m asl).

<u>Explanatory variables in the efficiency effect equation</u>

To identify possible determinant of inefficiency the following model is specified.

$$\sigma_{ui}^2 = \exp(w_0 + w_1 hhsex_i + w_2 hhage_i + w_3 hhysch_i + w_4 hhsize_i + w_5 hhwealth_\text{i} + w_6 tothive_\text{i} + w_7 distwt_\text{i} + w_8 exten_\text{i}) \quad (7)$$

The exogenous variables that are expected to exert influence the technical efficiency of honey producers includes, include sex (hhsex), age (hhage), and education status of the household head (hhysch); household size (hhsize); household wealth (hhwealth); total number of hives (tothive) and household access to institutions such as market (distwt) and extension service (exten).

These exogenous variables are expected to affect producers' performance either through their influence on the structure of the technology by which inputs are converted to output, or through their influence on the efficiency with which inputs are converted to output (Kumbhakar and Lovell, 2000).

5. Result and discussion

The data used in this paper is drawn from LIVES[1] baseline survey conducted in 2014. From the baseline dataset those engaged in honey production which are 556 were considered for this analysis.

5.1 Descriptive result

This section present the descriptive result of household characteristics, input use in apiculture production, volume of production and productivity and the gender role in apiculture production.

5.1.1 Household characteristics

[1] Livestock and Irrigated Value chains for Ethiopian Smallholders (LIVES)—an ongoing collaborative research for development project implemented by ILRI, IWMI, the Ministry of Agriculture, the Ethiopian Institute of Agricultural Research, the Ethiopian Ministry of Agriculture, regional bureaus of agriculture, livestock development agencies, regional agricultural research institutes—aim to improve competitiveness, sustainability and equity in value chains for selected high-value livestock and irrigated crop commodities in four regions (Tigray, Amhara, Oromia and SNNPR) of Ethiopia. Supported by Foreign Affairs, Trade and Development Canada (DFATD) the project is expected to last until March 2018.

As part of the project monitoring and evaluation framework a baseline survey was conducted in February –April 2014 on 5,000 households randomly selected using a multistage cluster sampling techniques from the ten project zones. Using electronic data collection method detailed data on socio-economic status and agricultural activities of the households during past production season (June 2012-July 2013) were collected. The survey were led by senior scientists from ILRI (Project website: http://lives-ethiopia.org)

The analysis of this paper is based on the data collected from 556 rural households (Table 1) selected from the four largest regions of the country (Tigray 183; Amhara, 193; Oromia, 117 and SNNPR, 63). In total female headed households constitute only 6.1% of the sample households however their share is higher in Tigray region revealing the difference in women participation in apiculture production across regions.

Table1: Household engaged in honey production

Region	Male		Female		Total
	No of households	%	No of households	%	
Tigray	162	88.5	21	11.5	183
Amhara	186	96.4	7	3.6	193
Oromia	113	96.6	4	3.4	117
SNNPR	61	96.8	2	3.2	63
Total	522	93.9	34	6.1	556

Traditional practice dominate honey production in Ethiopia and this is attested by our data where only 36.5% (203) of the sample households own improved bee hives (transitional or modern) (table 2). Interestingly however only 35.2% of male headed households (184 out of 522) owned improved bee hives compared to 55.8% of female headed households (19 out of 34) and the difference was found to be statistically significant ($p = .045$, two-tailed Fisher's exact test). This is probably because among other things handling traditional hives requires physical strength which limits the women participations. On the other hand notwithstanding the intensive management requirement the modern hives are relatively women friendly.

5.1.2 Hives ownership

Table 2: Distribution of beehives by sex of household head

Sex of household head	Beehive type					
	Traditional		Transitional		Modern	
	No of households	%	No of households	%	No of households	%

Male	408	78	21	4	163	31
Female	20	59	1	3	18	53
Total	428	77	22	4	181	33

On average a household own about 3.37 beehives (Table 3). Disaggregation by gender shows that male headed households own slightly more hives than their female counter part (3.4 as compared to 2.85). However the difference was found to be statistically insignificant (t= .729, p = .466). Studies shows that in the rural Ethiopia female headed households have less access to productive assets such as beehives however the fact that our data detect no difference in total number of beehives ownership between male and female headed household could indicates the success of the government and other developing partners that are working in the study area in targeting women and female household heads.

Table 3: Number of hives per households

Sex of household head	No of households	Mean	Standard Deviation	Minimum	Maximum
Male	522	3.40	4.35	1.00	40.00
Female	34	2.85	2.62	1.00	11.00
Total	556	3.37	4.27	1.00	40.00

Analyzing hives ownership by beehive type reveals that average households on average own 3.37 traditional, 3.27 transitional and 2 modern beehives (Table 4). Test results indicates that the difference is statistically significant (F=8.499, p = .000). This is expected because traditional method of production dominate the apiculture sub-sector. In addition the fact that improve hives are expensive further limit ownership of modern hives.

Table 4: Ownership of beehives per households by type of hives

Type of hives	Male		Female		Total	
	Mean	No of households	Mean	No of households	Mean	No of households

Traditional beehive	3.41	408	2.50	20	3.37	428
Transitional beehive	3.24	21	4.00	1	3.27	22
Modern beehive	1.94	163	2.39	18	1.99	181

5.1.3. Input use in honey production

As a further indication of the wide spread of traditional practices in honey production is the fact that the limited use of purchased inputs such as bee forage and other supplement. As shown in table 5 only 31.1% (173) of the sample households uses purchased apiculture input in the production period. Though the proportion of male households who used purchased input seems to be less that to that of their female counter part (30.8% compared to 35.5%) the difference was found to be statistically insignificant (Chi square with one degree of freedom 0.295, p=0.587). This shows that irrespective of the gender of the household head the use of purchased input is limited.

Table 5: Purchased input in apiculture production

Sex of household head	Yes		No		Total
	No of households	%	No of households	%	
Male	161	30.8	361	69.2	522
Female	12	35.3	22	64.7	34
Total	173	31.1	383	68.9	556

Though the use of purchased input is limited in general our analysis shows that compared to those who own traditional beehives higher proportion of households who own improved beehives use purchased inputs (28.3% compared to 43.3%) in the production honey during the production season (Table 6). This is because as mentioned above improved hives require intensive management and needs additional inputs such as wax. The implication here is that the development of apiculture sector should follow a holistic approach such that the introduction of improved beehives for example should be coupled with improved access to apiculture inputs.

Table 6: Purchased input in apiculture production by hive type

Type of hives	Yes	%	No	%	Total
Traditional	121	28	307	72	428
Transitional	15	68	7	32	22
Modern	73	40	108	60	181

Disaggregation at regional level shows that the proportion of household that used purchased apiculture input is limited which ranges from 23.3% in Amhara to 44.4% in SNNPR (Table 7) and the difference was found to be significant (Chi square with three degrees of freedom is 11.650 and p=0.009). This could indicate difference in access to inputs among regions or difference in household practices. To disentangle the exact reason for the observed difference in use of purchased input among regions needs further studies.

Table 7: Use of purchased/hired input for apiculture production by region

Region	Yes		No		Total
	No of households	%	No of households	%	
Tigray	59	32.2	124	67.8	183
Amhara	45	23.3	148	76.7	193
Oromia	41	35.0	76	65.0	117
S.N.N.P.R	28	44.4	35	55.6	63
Total	173	31.1	383	68.9	556

Beehives are the most common purchased apiculture inputs by the sample households. Of those who used purchased input (173) about 52.6% (91) purchased hives during the production season (Table 8). This could be related to availability of inputs as the district/woreda office of agriculture avails beehives inputs to farmers. On the other hand only 19.7% (34 households) and 16.2% (28 households) used purchased bee forage and supplement feed respectively. A number of factors could explain the limited use of purchased bee forage and supplement including lack of supply of inputs, limited economic access to input or less need for purchased inputs because of availability of adequate bee forage in particularly area.

Table 8: Common type of input purchased/hired

Type of input	Sex of household head				Total	
	Male		Female			
	Number	%	Number	%	Number	%
Beehives	85	52.80	6	50.00	91	52.60
Bee colonies	42	26.09	6	50.00	48	27.75
Labor for bee management	39	24.22	2	16.67	41	23.70
Bee forage	31	19.25	3	25.00	34	19.65
Supplemental feed	26	16.15	2	16.67	28	16.18
Bee keeping accessories	10	6.21	3	25.00	13	7.51
Others	22	13.66	3	25.00	25	14.45

Out of those who used purchased apiculture input excluding hired labor (154) a household on average spend about 677.02 ETB[2] during the production year and there is a high variation among households as confirmed by huge standard deviation (Table 9). Though the average cost of purchased inputs is 672.16 ETB for male and 734.58 ETB for female headed households the difference in average value of purchased input is not statistically significant for male and female headed households (t= -.197, p = .844). This is surprising given the fact that access to productive resources, credit and input market is different for male and female households in the rural setting (Quisumbing, 1996 Udry et.al, 1995).

Table 9: Value of purchased input for apiculture production

Sex of household head	No of households	Mean	Standard Deviation	Minimum	Maximum
Male	142	672.16	1076.24	18.00	7,900.00
Female	12	734.58	749.57	50.00	2,225.00
Total	154	677.02	1052.67	18.00	7,900.00

Excluding hired labor, out of those who own traditional hives 103 use purchased input and on average spend about 252.1 ETB during the production season (Table 10). The big cost item was

[2] 1ETB=0.00488 USD as of June 2, 2015

found to be bee colonies (653.6 ETB) followed by beehives (102.3ETB). On the other hand for beehives and bee colonies household spend about 192.5 ETB and 500 ETB for transitional and 663.4 ETB and 1,303.3 ETB for modern beehives. Further analysis indicate that the difference in average expenditure between traditional and improved hives is statistically significantly only for beehives (t = -3.776, p = 0.004). This is because the average price of improved hives is more expensive than that traditional one which is generally constructed from locally available materials.

Apart from the naturally available bee forage honey producers also uses purchased improved bee forage. In this regard households who own traditional hives spend about 67 ETB birr on bee forage whereas those who own improved hives spend about 84 ETB and the difference is found to be statistically significant (t = -2.381, p = 0.025). The difference in use of purchased forage could be attributed to the fact that those who own traditional hives mainly depend on naturally available forage.

Overall the data reveals that use of purchased input is related to the type of beehive household own (Chi square with two degrees of freedom is 8.4206 and p=0.015). As can be seen in table 10 irrespective of input type, those who owns improved beehives are more likely to use purchased input than those who own traditional one. This could be because compared to improved hives (transitional and modern), traditional beehives requires less purchased input (Gebremichael and Gebremedehin, 2014).

Table 10: Important inputs by bee hives

Type of input	Traditional		Transitional		Modern	
	Average (in birr)	No of households	Average (in birr)	No of households	Average (in birr)	No of households
Beehives	102.3	49	192.5	8	663.4	46
Bee colonies	653.6	25	500.0	3	1,303.3	27
Supplemental feed	71.8	13	34.8	2	138.2	21
Bee forage	67.0	26	40.3	3	82.8	12
Others	153.8	12	190.0	1	205.5	23
	252.1	**103**	**244.3**	**14**	**1,069.7**	**70**

5.1.4. Honey production and productivity

In the production season household on average produce about 25.14 kg of honey (Table 11). Though the data seem to suggest a slight difference between male (24.86 kg) and female (29.43) headed households the test results indicate that difference in mean honey production is not statistically significant (t = -.845, p = .398). This is consistent with the result presented in table 4 and 8 above where there is no statistically significant difference in total number hives ownership and use of purchased input between male and female households.

Table 11: Total honey production (in kg)

Sex of household head	No of households	Mean	Standard Deviation	Minimum	Maximum
Male	522	24.86	30.54	2.00	284.00
Female	34	29.43	30.65	3.00	114.00
Total	556	25.14	30.54	2.00	284.00

From traditional hive household produce 5.7 kg per hives (Table 12) and the yield ranges from 2 kg to 15 kg. The data seem to suggest that female headed household produce slightly higher honey per hive than their male counterpart (6.46 kg compared to 5.63 kg). However test result failed to provide conclusive evidence to ascertain that the difference in productivity between male and female headed households is statistically significant (t = -1.96, p = .050).

The yield from improved hives (transitional and modern) are found to be higher than the traditional one and the difference was found to be statistically significantly (F=305.86, p = .000). Household produced 13.77 kg and 16.01 kg per hives from transitional and modern hives. Though there seems to be a slight difference between male and female household heads the difference was found to be insignificant both for transitional (t = .840, p = .411) and modern hives (t = -.016, p = .988).

Table 12: Honey productivity by hive types

Type of hives		Mean	Standard Deviation	Minimum	Maximum	No of households
	Male	5.63	2.42	2.00	15.00	408

Traditional beehive	Female	6.46	3.33	2.50	13.50	20
	Total	5.67	2.47	2.00	15.00	428
Transitional beehive	Male	13.95	4.60	4.00	20.00	21
	Female	10.00	.	10.00	10.00	1
	Total	13.77	4.57	4.00	20.00	22
Modern beehive	Male	16.01	8.06	8.33	55.00	163
	Female	16.04	7.38	8.50	35.00	18
	Total	16.01	7.98	8.33	55.00	181

During the year there are three honey harvesting seasons. The seasons are directly related to availability flowering trees and plants which are the source of nectar which in turn correspond to the amount of rainfall. Higher rainfall is associated with abundant flowering plants which serves as the source of nectars for the bees. Thus in the main harvesting season honey production is higher as compared to dry season. As can be seen in table 13 irrespective of hives type production per hives is higher during the main season followed by small rainy season and dry season. On average household produce about 4.66 kg of honey per hive from tradition hives in main season and the yield decreases to 2.78 kg per hive in small rainy and further decreases to 2.15 kg dry season. The same trend is observed for transitional and modern hives.

As compared to small rainy and dry season, number of honey producers is also higher during the main season. A total of 416 household harvested honey from traditional beehives during the main season however only 150 households harvested during small rainy season and number of producers drastically decrease in dry season and reached 56. The same pattern is observed for transitional and modern hives as well as for male and female headed households. Lack of bee forage could be the main reason as to why yield and number of producers decreases.

Table 13: Honey yield across different season (kg/hive)

Hive type	Main season	Small rainy season	Dry season

		Average yield	N	Average yield	N	Average yield	N
Traditional beehive	Male	4.66	398	2.78	141	2.15	50
	Female	4.92	18	3.45	9	1.97	6
Transitional beehive	Male	11.9	21	5.67	6	4.5	2
	Female	10	1	.	0	.	0
Modern beehive	Male	13.54	160	10.24	36	8.64	11
	Female	12.78	18	7.8	5	12.5	2

On average household get about 5.55 kg, 13.37 kg and 16.01 kg of honey per traditional, transitional and modern hives (Table 14). Though use of purchased input is expected to increase yields the difference of yield between those who used purchased input and those who do not was found to be statistically significant only for modern hives ($t = -2.3856$, $p = 0.018$). This seems to suggest that use of purchased input does not have a positive effect on honey production under traditional bee keeping management. However it should be noted that the type of input and the intensities of input use under traditional bee keeping is very different from that of modern one.

Table 14: Honey production (kg/hive) by use of purchased/hired input

Type of hives	Use of purchased input	No of households	Mean	Standard Deviation	Minimum	Maximum
Traditional beehive	No	324	5.62	2.48	2.00	15.00
	Yes	124	5.38	2.50	2.00	13.50
	Total	448	5.55	2.48	2.00	15.00
Transitional beehive	No	12	13.04	5.18	4.50	20.00
	Yes	11	13.73	4.71	4.00	19.00
	Total	23	13.37	4.86	4.00	20.00
Modern beehive	No	114	14.94	7.23	8.50	47.00
	Yes	67	17.83	8.87	8.33	55.00
	Total	181	16.01	7.98	8.33	55.00

Since it requires low start up investment beekeeping is accessible to the poor and vulnerable. However our data reveals that in the majority of the case head of the households who are often adult male are responsible for the production of honey (Table 15). For the traditional hive it is quite understandable that the role of women is limited as it require physical fitness to put the hives in place and harvest honey.

Table 15: Responsibility of honey production by type of hives

Who is involved in apiculture production	Traditional beehive		Transitional beehive		Modern beehive	
	No of households	%	No of households	%	No of households	%
Head only	336	79%	17	77%	158	87%
Spouse only	9	2%	0	0%	5	3%
Head and spouse	39	9%	3	14%	5	3%
Head and/or male child	32	7%	2	9%	7	4%
Other	12	3%	0	0%	6	3%
Total	428		22		181	

5.2. Econometric result

A stochastic frontier specification was used to quantify the level of technical efficiency of small scale honey produces. The third moment of the OLS residual test (M3T) of Coelli (1995) was conducted to check the validity of the model. The test result shows that the OLS residuals skews to the left and this lend support to the stochastic frontier specification (Table 16).

Table 16: Estimation result of the stochastic production frontier and inefficiency effects model.

Production frontier function						
lntothon	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
lnpinput	0.023211	0.018304	1.27	0.205	-0.01266	0.059086
lnntrdh	0.372463***	0.036521	10.2	0.000	0.300884	0.444042
lnntrnsh	0.391742***	0.137867	2.84	0.004	0.121528	0.661956
lnnmodh	0.392462***	0.061534	6.38	0.000	0.271858	0.513066
lnnforg	0.028204*	0.014854	1.90	0.058	-0.00091	0.057316
lnland	0.130125***	0.039833	3.27	0.001	0.052054	0.208196
modh	0.774231***	0.077548	9.98	0.000	0.622239	0.926223
azzone	-0.08134	0.065831	-1.24	0.217	-0.21036	0.047692
cons	2.351325***	0.101235	23.23	0.000	2.152908	2.549741
Inefficiency effects model						
usigmas						
hhsex	1.019357	1.018005	1.00	0.317	-0.9759	3.014611
hhage	0.002337	0.017124	0.14	0.891	-0.03122	0.035899

hhysch	-0.02773	0.060076	-0.46	0.644	-0.14548	0.090012
hhsize	0.180136*	0.095672	1.88	0.060	-0.00738	0.367648
hhwealth	-9.98E-06	6.15E-06	-1.62	0.105	-2.2E-05	2.08E-06
tothive	-0.90627***	0.319411	-2.84	0.005	-1.5323	-0.28023
Distwt	0.00241*	0.001423	1.69	0.090	-0.00038	0.0052
Exten	0.241996	0.389373	0.62	0.534	-0.52116	1.005154
cons	-3.03526**	1.569789	-1.93	0.053	-6.11199	0.041473
vsigmas						
_cons	-1.0547	0.074123	-14.23	0.00	-1.19998	-0.90942
L. Likelihood	-514.88121					
χ^2	382.20					
N	545					
M3T Statistics	-1.5823319					

As can be seen in table 16 above the result shows that number of hives the household owns, use of improved technology (modern hives) land owned by the household and availability of natural forest which is the primary sources of nectar for bees are important input in the production of honey for small scale honey producers in Ethiopia.

Irrespective of their types, number of beehives were found to have statistically significant effect (P<0.001) on the amount of honey a household produce. This shows that small scale farmers are underutilizing the available input and the optimal number of hive ownership has not be reached. The output elasticity of the hives are 37%, 39% and 39% for traditional, transitional and modern beehives respectively.

Availability of forest and other vegetation measured in terms of forest coverage per household has positive and statistically significant effect (P<0.1) on the amount of honey produced by a households. In Ethiopia small-scale producer mainly depend on forest plants and natural vegetation as sources of bee forage and our result reflect this rather clearly. The immediate implication of using naturally available vegetation as a primary source of bee forage is that there is a high input-output ratio which makes the sector even more suitable for low income households.

Though honey production does not need large tracts of land the result showed that amount of land owned by a household positively affect the amount of honey production and effect was found to be significant (P<0.01). This could be because households that own large plot of land can afford to allocate more land for planting bee forage plants which directly affect the amount of honey production.

Use of improved technology particularly use of improved hives is also found to have significant effect (P=0.001) on total honey production. This is hardly surprising because compared to traditional hives the improved one both transitional and modern have allow farmers to increase honey production significantly.

On the other hand use of purchased input (bee forage) was found to have statistically insignificant effect (P= 0.205) on total honey production by the household. This could be because farmers use purchased input as a form of coping mechanize during dry season when there is shortage of bee forage rather than to increase honey production.

Similarly agro ecology zone was found to have no statistically significant effect (P=0.217) on honey production. This is probably because there are different bee species in the country with different adaptation capacity to the different agro- ecology zone.

The mean technical efficiency is equal to 0.797, implying that, on average, honey producers produce 80% of the maximum output. In other word about 20 percent of the potential output is lost to technical inefficiency. Here care should be taken in interpreting the technical efficiency score because the estimated technical efficiency is only relative to the best producers in the sample. Furthermore as noted by Coelli et.al (2005) the estimated efficiency level provide no information about the efficiency of one sample relative to the other. Therefore it should not be used to compare the result with other sample as it only reflect the dispersion of efficiency within each sample.

To identify factor that influence exogenous factors were included in the efficiency effect model. The choice of variables used as potential determinants in this paper has been guided by relevant literature and data availability.

Number of total hives, household size and distance to woredas town, household wealth, and whether the household head has a leadership role in the PA was found to have a statistically significant influence the technical efficiency of honey producers. While household wealth was found to only have marginally significant effect (Table 16).

Household that owns large number hives tend to be more technically efficient (P<0.001). This could be related to the advantages associated with economic of scale. Access to market and other intuitions proxied by distance to woredas towns in this paper is expected to influence the efficiency level of honey producers. In this regard the result shows that honey producers households that are located near to the woredas town are more efficient than household that are located very far and the different was found to be statistically significant (P<0.1) probability because households that have access to markets and institutions could get technical knowledge and skills in the production of honey.

Surprisingly access to extension services was found to have statistically insignificant effect on the technical efficiency of honey producers (P=0.534). This could indicates the ineffectiveness of the extension service that target small scale honey producers. The result is in line with the findings of SOS–Sahel-Ethiopia (2006) that identified lack of inadequate extension services in the area of honey production and marketing as one of the major constraints that affect the sub-sector.

6. Conclusion and implication

Though beekeeping and honey production started in Ethiopia a long time ago and the country has a huge potential for organic honey production, the production and productivity level of the sector is very low. This paper therefore tried to explore the status of honey production by small holders, investigate the technical efficiency of small scale honey producers and identify factors that explain efficiency differentials among small scale honey producers in Ethiopia by using a cross section data collected from 556 small scale honey producers.

The paper uses descriptive statistics to explore the current status of small scale honey production and a stochastic production frontier analysis to examine their technical efficiency. Test statistics suggested by Coelli (1995) has been conducted to check for the validity of the stochastic frontier specification and the result support the use of stochastic frontier model.

The result shows that consistent with other studies traditional practice dominate small scale honey production in Ethiopia. This is primarily reflected by the use of traditional hives by the majority of honey producers. Though different effort has been made to introduce improved hives, the effort was not effective. This present both opportunities and challenges to ameliorate the sector. By replacing the traditional one with the improved hive it is possible to increase production and productivity considerably. On the other hand there is a need come up with suitable and feasible improved hives that are both accessible to small scale farmers and easy to operate and maintain.

The finding also reveals that use of purchased inputs such as bee forage and other supplement is very limited among honey producers indicating that natural bee forage is the primary source of bee forage. This result is consistent with other research in the area (IMPS, 2005).Though this has a clear advantage in that honey produce from natural vegetation is organic and is free from agro-chemical contamination, depending on naturally available forage excessively makes honey producer more vulnerable to drought. In fact a study by Workneh, A., et.al, (2008) found drought as the primary constraint honey producer face. A number of factors including low awareness about the existence of bee forage other than the naturally available one, shortage of bee forage supply or limited access to purchased forage could explain why small scale honey producer excessively depend on natural. Though a detailed study is needed to identify the real reason why small scale honey producers depended on natural vegetation, the important point remain that to bring meaningful change the use of improved bee forage should be promoted.

As far as volume of production and productivity is concerned a clear message emerges from our analysis. Total honey production was found be about 25.14 kg per household during the year with no statistically significant difference between male and female headed households. The result further shows that the amount of total honey production directly correlate with the availability of bee forage and the use of purchased bee forage.

On the other hand on average honey yield from traditional hives was found to be 5.7 kg while 13.77 kg and 16.01 kg were harvested from transitional and modern hive respectively. The yield particularly for modern hives as found to be affected by the use of purchased input. Thus the paper submit that there is a clear connection between improved bee management and total production and productivity.

The result stochastic frontier model shows that the number of hives the household owns, whether the household used of improved apiculture technologies and availability of natural forest which is the primary sources of nectar for bees are important input that determine the amount of honey produced by small scale honey producers in Ethiopia.

The fact that number of hives determine the total amount of honey production shows that the current number of hive owned by small scale honey producers is less than optimal. One of the primary reasons for operating small number of hives particularly the improved one is the initial cost of the hives themselves and limited access to bee forage. Thus there is a need to improve farmer's access to credit services.

Use of improved technology particularly use of improved hives is also found to have significant effect on the total honey production. This could be used as another intervention points to improve the production and productivity of honey producers. In the past a number of effort has be made in to introduce modern hives, however the penetration rate was very low (Gallmann, P., and Thomas, H., 2012). The implication is that the importance of improved hive has long been recognized by policy maker and other development partners. The real hurdle in this regard is how to improve the adoption of improved hives. Gallmann, P., and Thomas, H., (2012) argued that apart from their price, the difficulty of working with modern hives discouraged adoption of modern hives. This resulted from emphasis on input supply rather than emphasis on bee husbandry. Thus from the technology perspective there is a need to introduce improved hives that can be constructed from locally available material. Furthermore, these improved hives should not require specialized knowledge or skill to operate them. The extension service on its part should provide capacity building training to farmers on how to construct and maintain improved hives and also link them with credit service providers.

The importance of forest plant as a source of bee forage consistently show up in our analysis. In the stochastic frontier model, availability of forest plant measured in terms of area under forest coverage per household was found to have statistically significant effect on the amount of honey produced by a household. In this situation small scale honey producers would have no incentive to invest on improved bee forage since they can produce honey without incurring any cost particularly for flowering plant. In this regard it is important to convince honey producers about the importance of using improved bee forage and encourage them to grow improve bee forage. At the same time there is a need to expand the use of indigenous flowering plant and shrubs as well as introduce improved bee forage seeds.

Technical efficiency of the honey producers considered in the analysis was found to be 80% indicating that about 21% is lost to technical inefficiency indicating that in Ethiopia small scale honey producer not only use less productive materials and input but also produce even less than what is possible with those technology and input set. Considering the traditional nature of honey production in the country a technical efficiency of 80% may be interpreted as a reasonable performance. However it should be noted that the estimated technical efficiency is only relative to the best producers in the sample.

As part of the stochastic production frontier analysis the paper shows that number of total hives, distance to woredas town, household wealth, and whether the household head has a leadership role in the PA have a statistically significant influence the technical efficiency of honey producers. While household size was found to only have marginally significant effect.

The finding suggest that policies that aim at increasing the total number of hives operated by honey producers is expected to increase farmer efficiency probably due to scale effect. Furthermore investing in rural infrastructural such as roads would provide venues for ideas and technologies to flow from the center to the periphery such that locational disadvantages of honey producers in remote villages with regards to market towns can be overcome and thus enhance their efficiency level.

Ethiopia has untapped potential in the production and marketing of honey and other bee products. Furthermore the sub-sector is suitable for small scale producers particularly for poor rural households that have limited livelihood opportunities. Thus by redressing the constraints and following a more focused approach it is possible to increase the contribution of the sub-sector as the same time benefit poor rural households.

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