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Technical efficiency of smallholder barley farmers: The case of Welmera district, Central Oromia, Ethiopia

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Crop production and productivity are not only inevitably affected by level of adoption of improved technologies and external factors but also the technical efficiencies of producers. The main objectives of this study are to estimate technical efficiency of sample barley farmers, assess determinant factors and compute yield loss due to inefficiency. Plot level data from 180 barley growers were collected through three stage systematic random sampling procedures. A one-step maximum likelihood was used to estimate stochastic frontier translog production function to determine the level of technical efficiency and its determinant factors. The estimated value of technical efficiency ranges from 0.11 to 0.99 with an average of 0.53 allowing inefficiency gap of 0.47 indicating the opportunity to increase barley output by 47% by using the same inputs mix and existing technology. The study found sex, age and education level of the household head, distance to all weather roads, credit service, group membership, extension contact, training, plot fragmentation, tenure status, and investment in fertilizers significantly impact technical efficiency. The result suggests the need to involve female headed households into extension and trainings, increase the education level of households through informal and formal literacy, inspire household membership into farmers' groups and enable them to share best practices from model and more experienced farmers, inspire barley producers to invest on fertilizers and strengthen rural micro finance institutions to provide credit at some reasonable costs.

Key words: Barley farms, translog production function, technical efficiency, Welmera.

INTRODUCTION

Ethiopia is currently following productivity-led agricultural transformation playing an active role in its economic transformation and making agriculture the main driver of growth. According to ATA (2014) the transformation of the agriculture is central to Ethiopia to reach middle-income country position by 2025. Research and development in this vital sector, therefore, helps to increase growth in agriculture and total factor productivity by increasing crop production and productivity through the development of best-fit new technologies, and

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increased adoption and utilization (Nicostrato and Mark, 2015). In its endeavor, Ethiopia completed its first Growth and Transformation Plan (GTP I) from 2010/2011 to 2014/2015 with some success and has already started its second phase five years Growth and Transformation Plan (GTP II) (FDRE, 2015). This strategic plan focuses on smallholder agriculture intensification through improved access to modern inputs like improved seed varieties, fertilizers and farming practices, and transform traditional subsistence to market oriented commercial agriculture.

The Ethiopian government has given more emphasis to barley research and development to boost production and productivity to food security. Research on barley improvement started in 1955, since then several new technologies, information and knowledge have been produced (Begna et al., 2014). According to MoA (2014), about 36 food and 16 malt barley varieties were released by the national research system and disseminated to the beneficiaries, and reported as they are under production. There is also evidence of barley technology adoption (Tiruneh et al., 2015; Yu and Nin-Pratt, 2014; Beshir et al., 2012). In an effect, barley showed steady growth in production and productivity over recent years. For example yields increased from 1.17 metric tons per hectare to 1.87 metric tons per hectare; and total production grew from 1.0 million tons in 2005 to about 1.9 million tons in 2014 (CSA, 2005, 2014). However, this productivity of barley is not as expected as compared to the yield of 3.5 metric tons per hectare obtained by progressive farmers (Begna et al., 2014) and 5 metric tons per hectare under on-station (Fekadu et al., 2011), indicating a huge potential of increasing productivity.

Crop yields and productivity are not only inevitably affected by weather conditions, quality of seeds and varieties, input prices, amount of fertilizers and farming practices but also the efficiency of production (Tiruneh and Geta, 2016; Debebe et al., 2015; Alemu et al., 2014; Ahmed et al., 2013; Yami et al., 2013). The efficiency of agricultural production reflects the effectiveness and describes the quality of managing the farm. Some argued that technology adoption and area expansion improve production and productivity of crops (Kamruzzaman and Mohammad, 2008; Haji, 2006). However, the first option requires a huge financing for technology generation and dissemination, the second option is hardly possible since land is limited and overly subdivided into small units which resulted in very fragmented production systems.

Certainly, production and productivity cannot only be increased by adoption and area expansion but also by enhancing the efficiency level of farmers to attain the maximum possible level of output from inputs at the disposal of the farmers and available technology. This last option requires identifying the level of efficiency and factors influencing inefficiencies (Tiruneh and Geta, 2016; Alemu et al., 2014; Gebregziabher et al., 2012; Asefa, 2012; Alene et al., 2006).

Thus, improving crop production and productivity among smallholder producers through efficiency requires a good knowledge of the current efficiency level characteristic in the area as well as factors determining efficiency levels. There have been small empirical studies conducted to estimate level of efficiencies and identify its determining factors for major crops including barley (Wassie, 2014; Alene and Zeller, 2005) and reported a significant level of inefficiencies, and no studies computed and highlighted the loss of outputs due to inefficiency. To the best of the authors' knowledge there are no similar studies started in the study area. Moreover, it is important to update the information based on current inputs and technologies. Therefore, this study was carried out to estimate technical efficiency of smallholder barley production, identify variables affecting technical efficiency and compute frontier output and amount lost by an average efficient producer.

METHODOLOGY

Study area

The study was conducted in Welmera district of Addis Ababa Zuria Special zone of Oromia, Regional State in Ethiopia. Welmera district is one of the eight administrative units of the Addis Ababa Zuria Special zone of Oromia Regional State. Geographically, the district is located between 8°50'-9°15'N latitude and 38°25'-38°45'E longitude, and the altitude from 2060 to 3380 m above sea level. The area is chosen based on its potential to barley production.

Sampling procedure and sample size

A three-stage sampling technique was employed. In the first stage, study district was purposively selected based on the extent of barley production. In the second stage, six *kebeles* (note that *Kebele* is the lowest administrative unit in the Ethiopian condition) were selected from the selected district based on the discussion with district level agricultural extension experts. Finally, from a list of barley growers obtained from extension offices at each *Kebele* level, 180 sample households were selected using systematic random sampling.

Data source and collection

The enumerators were recruited and trained to facilitate the job of primary data collection. The process was supervised by the researcher and the secondary data were extracted from information documented at various levels (Agricultural Office, Holetta Agricultural Research Center (HARC) and Cooperative Offices) and from published and unpublished sources. Detailed information on households' socioeconomic and demographic characteristics, farm characteristics, inputs utilization, output produced, institutional and policy related variables were collected from selected farm households. The survey was conducted from July to August of 2013.

Data analysis

To achieve the study's objectives, both descriptive and inferential statistics were used. Descriptive statistics like means, standard deviations, percentages and frequency counts were used in describing socioeconomic characteristics of households, inputs, output variables, frequency distribution efficiency levels and responses on the constraints of barley production. A stochastic frontier analysis with one step approach was employed in which both technical efficiency and its determinant factors were analyzed simultaneously using the econometric software, FRONTIER 4.1 computer programme.

Analytical framework

In this study, the stochastic frontier analysis approach was adopted to measure the technical efficiency of barley farms. The model was independently proposed by Aigner et al. (1977) and Meeusen and Broeck (1977). The merits for this approach over Data Envelopment Analysis (DEA) (non-parametric) is that it accounts for a composite error term (one for statistical noise and another for technical inefficiency effects) in the specification and estimation of the frontier production function. For a number of reasons, the stochastic frontier analysis (econometric) approach has generally been preferred in the empirical application of stochastic production function model in the developing countries' agriculture like Ethiopia. This might be due to, first, the assumption that all deviations from the frontier arise from inefficiency as postulated by DEA is hard to accept, given the inherent variability of smallholder agricultural production due to external factors like pests and weather conditions. Second, most farms are very small and operated by family labor and hence farm records kept rarely. The available data on barley production are most likely subject to measurement errors. Therefore, the stochastic frontier production required for estimating plot level efficiency is specified as:

$$Y_i = \exp(X_i\beta + V_i - U_i) \quad (1)$$

where Y_i denotes the output for the i^{th} sample farm, X_i represents a (1 × K) vector whose values are functions of inputs and explanatory variables for the i^{th} farm, β is a (K × 1) vector of unknown production parameters to be estimated, V_is are assumed to be independent and identically distributed random errors which have normal distribution with mean zero and unknown variables, σ_v^2, that is $V_i \sim N(0, \sigma_v^2)$ and U_is are non-negative unobservable associated with the technical inefficiency of production such that for a given technology and levels of inputs, the observed output falls short of its potential output ($U_i \sim N(0, \sigma_u^2)$ or it is a one-sided error term (U ≥ 0) efficiency component that represents the technical inefficiency of the farm. In short, U_i estimates the shortfall in output Y_i of barley from its maximum value given by the stochastic frontier function.

In other words, the basis of a frontier function can be illustrated with a farm using n inputs for barley (X_1, X_2,….., X_n) to produce output Y of barley. Efficient transformation of inputs into output is characterized by the production function $f(X_i)$, which shows the maximum output obtainable from various input vectors. The stochastic frontier production function assumes the presence of technical inefficiency of production. Hence, the function is defined as:

$$Y_i = f(X_i, \beta) + \varepsilon_i \; ; \forall \; i = 1,2, - - - n{=}230 \quad (2)$$

The stochastic frontier analysis has been used in many studies. For example, Yami et al. (2013), Beshir et al. (2012), Jaime and Salazar (2011), Tan et al. (2010), and Daniel et al. (2008) used this approach and the approach specifies technical efficiency as the ratio of the observed output to the frontier output, that means the technical efficiency of an individual farmer or farm is defined as the ratio of observed output and the corresponding frontier output, given the state of available technology, and presented as follows:

$$\mathrm{TE} = \frac{F(X_i;\beta).\exp(v_i - u_i)}{F(X_i;\beta).\exp(v_i)} = \exp(-u_i) \quad (3)$$

where F (X_i;β).exp(v_i-u_i) is the observed output (Y) and F (X_i,β).exp(v_i) is the frontier output(Y^*). Pursuing Battese and Coelli (1995), the error term (v_i) permits random variations in output due to factors outside the control of the farmer like weather and diseases as well as measurement error in the output variable, and is assumed to be identically, independently and normally distributed with mean zero and constant variance (σ_v^2), that is, $v_i \sim N(0, \sigma_v^2)$. The u_i is the inefficiency component of the error term and a one-sided non-negative (u>0) random variable, is assumed to be independently distributed as truncations at μ of the normal distribution and variance (σ_u^2), that is, $u_i \sim N(\mu_i, \sigma_u^2)$, but if $u_i = 0$, the assumed distribution is half-normal. The technical inefficiency model suggested by Battese and Coelli (1995) exemplified by:

$$\mu_i = Z_i\delta_i \quad (4)$$

where Z_i is a (1 × M) vector of exogenous explanatory variables associated with the technical inefficiency effects in the i^{th} time period, δ_i is an (M × 1) vector of unknown parameter to be estimated.

As mentioned earlier, this study employed the single stage maximum likelihood estimation method in estimating the technical efficiency levels and its determinants simultaneously. This estimation procedure guarantees that the assumption of independent distribution of the inefficiency error term is not violated. The maximum likelihood estimation of the stochastic frontier model yields the estimate for beta (β), sigma squared (σ^2) and gamma (γ), and are variance parameters; γ measures the total variation of observed output from its frontier output. The study used the parameterization following Battese and Coelli (1995) and given as, $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma^2{}_u / (\sigma_v^2 + \sigma_u^2)$, where the gamma lies between zero and one (0 ≤ γ ≤ 1). If the value is very close to zero, then the deviations are as a result of random factors and/or if the value is very close to 1, then the deviations are as a result of inefficiency factors from the frontier.

Model specification

Following Aigner et al. (1977), the translog production function has been used recently by many studies to estimate technical inefficiency (Tiruneh and Geta, 2016; Geta et al., 2013; Yami et al., 2013; Beshir et al., 2012). Moreover, the uses of different functional forms have a distinct but small impact on estimated efficiency (Kopp and Smith, 1980). Therefore, the translog production function stated in Equation 6 is used for the study mainly for its flexibility for which it places no restriction unlike the Cobb-Douglas production function.

$$lnY_i = \beta_0 + \sum_{i=1}^{5} \beta_i lnX_i + (v_{i-}u_i) \quad \text{(Cobb-Douglas)} \quad (5)$$

$$lnY_i = \beta_0 + \sum_{i=1}^{5} \beta_i lnX_i + \frac{1}{2}\sum_{i=1}^{5}\sum_{j=1}^{5} \beta_j (lnX_i)(lnX_j) + (v_{i-}u_i) \quad (6)$$

where i=1,2,- - - n=230, and **X**= vector of five input variables.

Table 1. Selected farm households from each *Kebele* (Own Sampling Design).

Kebele	**Total households**	**Sample households**
Burkusami Gebeya Robi	672	37
Telecho Gebriel	540	30
Bekekana Kore Odo	503	28
Welmera Chokie	664	36
Wajitu Harbu	452	25
Geresu Sida	446	24
Total	3277	180

Based on the aforementioned model, a stochastic frontier model for barley farmers is given by:

$$ln(output)_i = \beta_0 + \beta_1 ln(Area)_i + \beta_2 ln(Fert)_i + \beta_3 ln(Oxndays)_i + \beta_4 ln(seed)_i + \beta_5 ln(clab)_i + 1/2\ \beta_{11} ln(Area)^2 + 1/2\ \beta_{22} ln(Fert)^2 + 1/2\ \beta_{33} ln(Oxndays)^2 + 1/2\ \beta_{44} ln(seed)^2 + 1/2\ \beta_{55} ln(clab)^2 + \beta_{12} ln(Area)\ ln(Fert) + \beta_{13} ln(Area)\ ln(Oxndays) + \beta_{14} ln(Area) ln(seed) + \beta_{15} ln(Area)\ ln(clab) + \beta_{23} ln(Fert)\ ln(Oxndays) + \beta_{24} ln(Fert)\ ln(seed) + \beta_{25} ln(Fert)\ ln(clab) + \beta_{34} ln(Oxndays)\ ln(seed) + \beta_{35} ln(Oxndays) ln(clab) + \beta_{45} ln(seed) ln(lab) + vi - u_i \quad (7)$$

where *output* represents total yield of the i[th] plot in kilo gram (kg); *Area* represents operational area of barley of the i[th] plot in hectare (ha); *Fert* represents the total amount of inorganic fertilizers used per plot in kg; *Oxndays* represents the amount of oxen days used for plowing from land preparation to planting, *Seed* represents the amount of seed used per plot in kg; cl*ab* represents the total cost of labour and herbicide (because herbicide was used instead of hand weeding) in Birr (Birr is the Ethiopian currency), and *ln* represents Natural logarithm.

The specification of inefficiency model for barley individual producer at a plot level is given as:

$$\mu_i = \delta_0 + \sum_{j=i}^{15} \delta_j Z_{ji} \quad (8)$$

$$\mu_i = \delta_0 + \delta_1 Sex + \delta_2 Age + \delta_3 Educ + \delta_4 Fsize + \delta_5 Proxwroad + \delta_6 Acredit + \delta_7 Livestock + \delta_8 Offrmy + \delta_9 Gpmship + \delta_{10} Ext + \delta_{11} Train + \delta_{12} Frmsize + \delta_{13} Frgmnt + \delta_{14} Tenurstatus + \delta_{15} Costfert \quad (9)$$

Status of barley production

Ethiopia is home for the great diversity of barley in terms of morphological types, genetic races, disease resistant lines, and endemic morph types (Abtew et al., 2015; Fekadu et al., 2011; Bonman et al., 2005). Barley has been produced in Ethiopia since ancient times. It is one of the most important staple food crops both as food and malt. However, Ethiopia produces mostly food barley, with its share estimated to be 90% (Alemu et al., 2014).

Barley is cropped both in the main season (Meher) using June to September rains and off-season (belg) using March to June rains. However, the major barley production is in the main season and the off-season season is irregular throughout Ethiopia characterized by a little grain production. Farming of crops under rain fed condition is the main agricultural production activity. Barley grain is used to prepare various type of food, and local and industrial beverages. There are four major growing areas of barley, namely, Oromia, Amhara, Southern Nations and Tigray regions which account for about 99.5% of the total annual barley grain production (MoA, 2014). Nationally, barley ranked fifth preceded by tef, maize, sorghum and wheat, and again ranked fifth in Oromia region preceded by tef, maize, wheat and sorghum (CSA, 2012) and finally ranked second in the study area following wheat in area of production (Tiruneh and Geta,2016).

The national agricultural research and extension system generated barley technologies and disseminated to large number of farmers during the last more than four decades to enhance barley productivity. However, the productivity level is still low which could be marked mainly by inefficiencies in using the existing technologies. Therefore, knowing the technical efficiency level and its determinant factors need to be analyzed.

RESULTS AND DISCUSSION

Estimation of productivity parameters and determinant factors

The summary of descriptive statistics of variables used in the econometric models and the results of hypothesis testing are presented in the Appendices 1 and 2.

The coefficients of barley area, amount of fertilizers, oxen days and seed used were positive and significant implying that an increase to some optimum level in these inputs would increase barley output. The coefficients of the square of barely area, interaction of barley area with fertilizer, oxen days, seed and cost of labor were positive and significant implying that an increase in these inputs would increase barley yield while the square of fertilizers, oxen days and cost of fertilizers were negative at 1% significant level.

About 15 socioeconomic of the household heads, institutional factors and plot level characteristics were assumed to affect level of technical efficiency of barley farmers in the study area. The simultaneously estimated maximum likelihood results show that 11 variables (sex, age and education of the household head, and distance to all weather roads, access to credit, group membership, extension contact, training, farm fragmentation, tenure status and investment on fertilizers) were found to affect inefficiency of barley productivity significantly.

The coefficient of sex had a positive effect on technical efficiency of barley farmers at 1% level of significance. Indicating that male headed households operating more efficiently than their female counterparts. This might be due to the fact that men had more resource endowments (for example land, training, improved inputs) and physical

Table 2. Summary of socioeconomic variables used in the efficiency model (Own Survey Data, 2013).

Variable	Description of variable	Mean (SD), %
Sex	Sex of the household head (1= male, 0=female)	89.4
Age	Age of the household head in Years	43.9 (11.3)
Educ	Stands for formal education attained by the household head in years	3.8 (3.7)
Fsize	Stands for Family size in Labor force unit	3.55 (1.5)
Proxwroad	Stands for Proximity with all weather road in walking minute from the residence	20 (22)
Acredit	Stands for credit accessed in Ethiopian Birr	926.4 (1704.20)
Livestock	Livestock holding in TLU	7.83 (4.17)
Offrmy	Stands for off-farm income earned in Ethiopian Birr	3961.8 (9018.5)
Gpmship	Stands for group membership (1= if the household belongs to more than one group, 0= otherwise)	32.2
Ext	Stands for extension contact in number of days	7 (7)
Train	Stands for training attended by the family member in number of days	1 (1)
Frmsize	Stands for farm size (operational farm land) in ha	2.5 (1.52)
Frgmnt	Stands for fragmentation (number of barley plots) the household had	1.27 (0.5)
Tenurstatus	Stands for tenure status (1= if the household used own farm, 0= otherwise)	86
Costfert	Stands for proportion of cost of fertilizers (cost of fertilizers/total variable cost)	0.36 (0.12)

fitness to some of the agricultural operations. Daniel et al. (2008) and Kibaara and Kavoi (2012) found similar results. While Yami et al. (2013) reported opposite results for waterlogged area wheat farmers in Ethiopia. The variable age was negative and statistically significant at 1% significance level. This means that elder farmers may take benefit of their experiences to use inputs more efficiently to their barley production. Chiona et al. (2014), Mazumder and Gupta (2013), Dlamini et al. (2012) and Asogwa et al., (2012) reported similar results. While Yami et al. (2013), Simonyan et al. (2011), and Jaime and Salazar (2011) reported opposite results. Education was negative and statistically significant at 5% significant level. This means that more years of schooling will improve technical efficiency in barley production. Education enables farmers to better access to, understand and interpret agricultural information to adopt technologies and use them more efficiently. Tiruneh and Geta (2016), Geta et al. (2013), Yami et al. (2013), and Asogwa et al. (2012) reported similar results.

The result shows that distance to all weather roads affected technical efficiency of barley farmers positively and significantly at 1% significance level against the priori expectation, indicating that farmers living far from all-weather roads operate efficiently than the roadside residents. This might need further investigation by including more study areas. The findings of this study show that access to credit is found to affect technical efficiency positively and significantly at 1% significance level by easing financial constraints on inputs purchase. This means that access to credit would have the potential to improve technical efficiency of barley farmers in the study area. Being membership to more than one farmers' group (because by default, a head famer is a member of one for five development team) affects technical efficiency positively and significantly at 1% significance level. Implying that membership in more than one farmers' group will improve technical efficiency through better access to agricultural information and sharing of best practices among members. Daniel et al. (2008) and Kariuki et al. (2008) reported similar results. The coefficients of frequency of extension contact and training were also found negative and significant at 1% level, indicating that having more frequent extension contact and participating in training activities could improve technical efficiency of farmers as extension agents provide information on technologies to farmers. Mango et al. (2015) and Obare et al. (2010) found similar results.

The coefficient of farm fragmentation was found to be negative and significant at 10% level, indicating that farmers having more plots of barley were more efficient. Tiruneh and Geta (2016), Yami et al. (2013) and Tan et al. (2010) reported similar findings. The coefficient of tenure status was negative and statistically significant at less than 1% level, indicating that farmers with own plots of barley are more efficient than renters and/or share croppers. Kariuki et al. (2008) reported similar results. Cost of fertilizers or investment on fertilizers was found to be negatively affecting technical inefficiency of barley farmers at less than 1% significance level, indicating investing more in fertilizers will improve barley productivity. Giannakas et al. (2001) reported similar results.

Estimation of technical efficiency, spatial distribution and yield gap

The core feature of stochastic production frontier is the ability to estimate individual farm specific efficiency level.

Table 3. Maximum likelihood estimates of inefficiency effects model.

Variable	Coefficient	t-value
Constant (β_0)	0.381	0.295
Ln (Area)[A]	0.273***	2.90
Ln (Fertilizer)[F]	0.40***	4.257
Ln (Oxen)[O]	0.851***	-9.05
Ln (Seed)[S]	1.323***	-14.065
Ln (Costlabor)[C]	-0.137	-0.146
Ln $(A)^2$	1.078***	-14.696
Ln $(F)^2$	-0.334***	-4.557
Ln $(O)^2$	-0.345***	-4.097
Ln $(S)^2$	-0.441***	-6.01
Ln $(C)^2$	-0.075	-1.028
Ln(A)Ln(F)	0.077	0.87
Ln(A)Ln(O)	1.285***	14.468
Ln(A)Ln(S)	0.208**	2.34
Ln(A)Ln(C)	0.313***	3.53
Ln(F)Ln(O)	0.239	0.269
Ln(F)Ln(S)	0.082	0.093
Ln(F)Ln(C)	-0.053	-0.622
Ln(O)Ln(S)	0.174	0.196
Ln(O)Ln(C)	-0.156*	-1.76
Ln(S)Ln(C)	0.05	0.056
Inefficiency model		
Constant (δ_0)	-0.044	-0.764
Sex	-0.396***	-10.51
Age	-0.794***	-3.078
Education	-0.542**	-2.172
Family size	-0.24	-0.465
Distance TAWRs	-0.171***	-3.86
Credit	-0.002***	-2.93
Livestock	-0.05	-0.15
Off-farm income	0.002	1.307
Membership	-0.609***	2.79
Extension contact	-0.94***	-8.39
Training	-0.273*	-1.956
Farm size	-0.282	-0.12
Fragmentation	-0.675*	-1.86
Tenure status	-0.144***	-.8.536
Cost of fertilizer	-0.135***	-9.31
σ_s^2	0.153***	5.203
γ	0.795***	3.458

*,**,*** show significant at 10, 5 and 1%, respectively.

This study used data collected from 230 barley farms of 180 households. The inefficiency model variance, γ was estimated to be 0.795 and statistically significant at 1% level, implying about 79.5% variation in barley output among farms was due to technical inefficiencies while about 20.5% came from external factors (Table 3). Table 4 presents the spatial distribution of technical efficiencies and average yield gap due to inefficiency. The result shows an enormous gap in technical efficiency between farmers. The majority (56.9%) of the farmers score a technical efficiency levels between 0.41 and 0.70 and about 28.7% score below 0.4 levels. The average

Table 4. Spatial distribution of technical efficiency and yield gap of barley producers (Own Survey Data, 2013).

Range of technical efficiency	Frequency	Percent
0.11-0.4	66	28.7
0.41-0.7	131	56.9
≥ 0.71	33	14.4
Total	230	100
Minimum TE score (%)	11	
Maximum TE score (%)	99	
Mean TE score (%)	53	
Observed output (kg/ha)	1800	
Frontier output (kg/ha)	3396	
Output lost due to inefficiency (kg/ha)	1596	

technical efficiency level of barley farms in the study area was estimated to be 0.53 ranging from 0.11 to 0.99, which shows a substantial technical inefficiency exiting and there is a huge room to increase barley output by about 47% through adopting best practicing farmers' practices using the same combination of inputs and existing technology. As mentioned earlier, the average yield was 1800 kg/ha with a mean technical efficiency score of 53% and the frontier yield was computed to be 3396 kg/ha if an average farmer had used the existing inputs and technologies efficiently. Therefore, on average, 1596 kg/ha of barley yield was lost due to inefficiency effects. According to FDRE (2015), the government of Ethiopia has set a strategy to raise the production and productivity of non-stalk cereals like barley from 2.1 to 3.1 ton/ha during its GTP II plan period by using mainly improved agricultural technologies. However, the results of this study suggest that it is possible to increase the productivity of barley by using the existing inputs and technology through improving the technical efficiency of farmers via determinant factors.

CONCLUSION AND SUGGESTIONS

The main objectives of this study were to assess the technical efficiency of barley smallholder farmers, sources of technical efficiencies and compute yield loss from inefficiency effects in Welmera district of Oromia region. The study used translog stochastic frontier function with a one-step approach to achieve its objectives. The results showed that a significant variation in technical efficiency scores ranging from 0.11 to 0.99 with an average of 0.53, implying that there is a wider room for increasing barley production by about 0.47, to operate on full technical efficiency frontier level by simply adopting best practices of model farmers. Concerning the spatial distribution of farm level technical efficiency scores, the majority (56.9%) of the farmers score a technical efficiency levels between 0.41 and 0.70 and about 28.7% score below 0.4 levels.

Among the strategy variables considered in an inefficiency effects model, sex, age and education level of the household head, distance to all weather roads, credit service, group membership, extension contact, training, plot fragmentation, tenure status and investment in fertilizers were identified to have higher influence on technical efficiency in barley production in the study area.

In order to improve the efficiency level of barley farmers, the result suggests the need to involve female headed households into extension and trainings, increase the education level of households through informal and formal literacy, inspire household membership into farmers' groups and enable them to share best practices from model and more experienced farmers, inspire barley producers to invest on fertilizers and strengthen rural micro finance institutions to provide credit at a reasonable costs.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Appendices

Appendix 1. Summary of variables used in the econometric models (Own Survey Data, 2013).

Input variable	Units	Minimum	Average	Maximum	Std. Deviation
Continuous					
Yield	Ton/ha	0.6	1.8	3.8	0.7
Area	ha	0.06	0.55	2.75	0.41
Seed	Kg/ha	105.7	129.17	156.5	13.4
Fertilizer	Kg/ha	30.77	134.46	491.67	70.9
Oxen-days	days/ha	14.25	18.09	21.85	1.95
Cost of labor	birr/ha	750	1282.90	1838.70	238.50
Age of HHH	years	24	43.9	78	11.3
Education	years	0	3.8	12	3.74
Family size	LFU	1	3.55	8.57	1.5
Distance to all WRs	minute	1	20	120	22
Credit	birr	0	926.40	10000	1704.20
Live stock	TLU	1.04	7.83	27..3	4.17
Off-farm income	Birr	0	3961.80	94600	9018.50
Extension contact in days	Number	0	7	42	7
Trainings in days	Number	0	1	4	1
Farm size	Ha	038	2.5	9.13	1.52
Fragmentation	number	1	1.27	4	0.5
Cost of fertilizer	proportion	0.11	0.36	0.72	0.12
Discrete	**Labels**			**Frequency**	**Percent**
	Female=0			19	10.6
Sex of HHH	Male=1			161	89.4
	Total			180	100
	1, if the household belongs to >1 FG			58	32.2
Membership	0 otherwise			122	67.8
	Total			180	100
	Own=1			198	86
Tenure status	Rented=0			32	14
	Total			230	100

Appendix 2. Summary of tested hypotheses (Own Survey Data, 2013).

Hypothesis	$L(H_o)$	LR(λ) statistics	critical χ^2 value	DF	Decision
1. H_0: $\beta_{ij} = 0$	-104.22	142.62	18.3	10	H_0 rejected
2. H_0: $\gamma = 0$	-77.24	88.68	2.7*	1	H_0 rejected
3. H_0: δ_1 = --- = δ_{15}=0	-53.54	41.28	24.99	15	H_0 rejected

*Shows it was taken from Table 1 of Kodde and Palm (1986).