Technical Efficiency of Sorghum Production: The Case of Smallholder Farmers in Konso District, Southern Ethiopia

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Abstract

This study aims to analyze the technical efficiency of sorghum production by smallholder farmers in Konso district, Southern Ethiopia using cross sectional data collected from a sample of 124 sorghum producing households. Individual levels of technical efficiency scores were estimated using the Cobb-Douglas functional form, which was specified to estimate the stochastic production frontier. The estimated stochastic production frontier model indicated that input variables such as land size, fertilizer (Urea and DAP), human labour, oxen power and chemicals (herbicides or pesticides) found to be important factors in increasing the level of sorghum output in the study area. The result further revealed significant differences in technical efficiency among sorghum producers in the study area. The discrepancy ratio, which measures the relative deviation of output from the frontier level due to inefficiency, was about 90%. The estimated mean levels of technical efficiency of the sample households was about 69%, which shows existence of a possibility to increase the level of sorghum output by about 31% by efficient use of the existing resources. Among the household specific socio-economic and institutional factors hypothesized to affect the level of technical inefficiency, age, education level, family size, off/non-farm activities, extension contact, livestock holding, plots distance and soil fertility status were found to be significant in determining the level of technical inefficiency of sorghum production in the study area. Hence, emphasis should be given to improve the efficiency level of those less efficient households by adopting the practices of relatively efficient households in the study area. Beside this, policies and strategies of the government should be directed towards the above mentioned determinants.
Keywords: Technical efficiency; SPF; Smallholders; Konso; Sorghum production.

1. Introduction

In Ethiopia, cereals are the major food crops both in terms of area coverage and volume of production. According to CSA [1] report, of the total area and production under crops, cereals accounted for about 80.78% and about 87.31% of the total production in quintals, respectively. The same source also indicated that, there was an increase in total food grain production from 251,536,62.39 metric ton in 2013/14 to 270,396.04.80 metric ton in 2014/2015. However, this increment in output could not be attributed to improvement in productivity alone as there was simultaneous increase in the size of cultivated land from 12,407,473.46 hectares to 12,558,444.55 hectares in the same period.

Smallholders account for 96% of the total area cultivated and generate the key share of total production for the main crops. Cereals are predominantly produced by smallholders and are consumed as food, and the by-products are fed to livestock [2]. In Ethiopia, sorghum accounts for the third largest share of total cereal production. Area under sorghum cultivation expanded from 1.83 million hectare in 2014/15 to 2.01 million in 2015/16 [3]. Sorghum is the single most important staple in drought prone areas; The trade status of the country from 2005 – 2010 shows that, import in all years and most of the sorghum import takes the form of food aid [4].

In southern region, from the total land size of 1,110,931.29 hectares planted to all grain crops, cereals covered 883,290.78 hectares with a total production of 20,455,69.44 metric ton. The production of sorghum is 247,740.29 metric ton and total area coverage under sorghum is 116,887.44 hectare and average yield per hectare is 21.19 quintals [1]. From the total land size of 63,733.25 hectares planted with all grain crops in Segen people's zone, cereals covered 51,426.38 hectares with a total production of 888,919.24 quintals. And the production of sorghum is 169,497.24 quintals which is the third in terms of production preceded by maize and teff and total area coverage under sorghum is 11,638.85 hectare and average yield per hectare is 14.56 quintals [1].

Among the districts of Segen Area People's zone, Konso district is known for cereal production especially sorghum followed by maize and teff. Out of the total 27,600.23 hectares of land allocated for cereals, sorghum

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occupies 12,604.67 hectares or 45.67% of the total land allocated for cereal crops in the district. In 2014/15 production year, the total production and productivity of sorghum was 165,373.27 quintal and 13.12 quintal per hectare, respectively, which is less than the regional productivity of 21.19 quintal per hectare (KDARDO, 2015). In this area depending on the rainfall, several hectares are grown annually. However, productivity is as such not much. Therefore, knowledge about the level of technical inefficiency of smallholder sorghum producers in the production and the underlying socio-economic and institutional factors causing inefficiency may help to assess the opportunities for increasing agricultural production. This study thus aims to contribute towards a better understanding of potential production capacity of this crop using extended efficiencies measurement procedures.

The highlands of Konso are densely populated and population is growing rapidly. The pressure on land is increasing, resulting in marginal lands to be taken into production and problems resulting from overstressing the farming system. Lately, declining soil fertility and growing population increase the pressure on limited land resources and people are unable to hold large stocks of food [5]. Even though, cereals especially, sorghum are the most predominate in the cropping pattern in Konso district in which this study was carried out, how much farmers are efficient in the study area was not known. Albeit there is lack of pertinent studies on technical efficiency of the smallholder farmers in sorghum production and the determinants of the variability of the efficiency levels among farmers in the study area. Hence, this study tries to analyze the technical efficiency of sorghum production in Konso district, which is known for the production of sorghum crop and aims to bridge the prevailing information gap by providing empirical evidence on smallholder resource use efficiency.

2. Research Methodology
2.1. Description of the Study Area
The study area is located about 600 km south of Addis Ababa at $5^{o}10^{'}$ – $5^{o}40'$ N latitude and $37^{o}00'$ – $37^{o}40'$E longitude. The total land area of the District is 2,274 sq.km. [6].

Figure-1. Location of Konso district
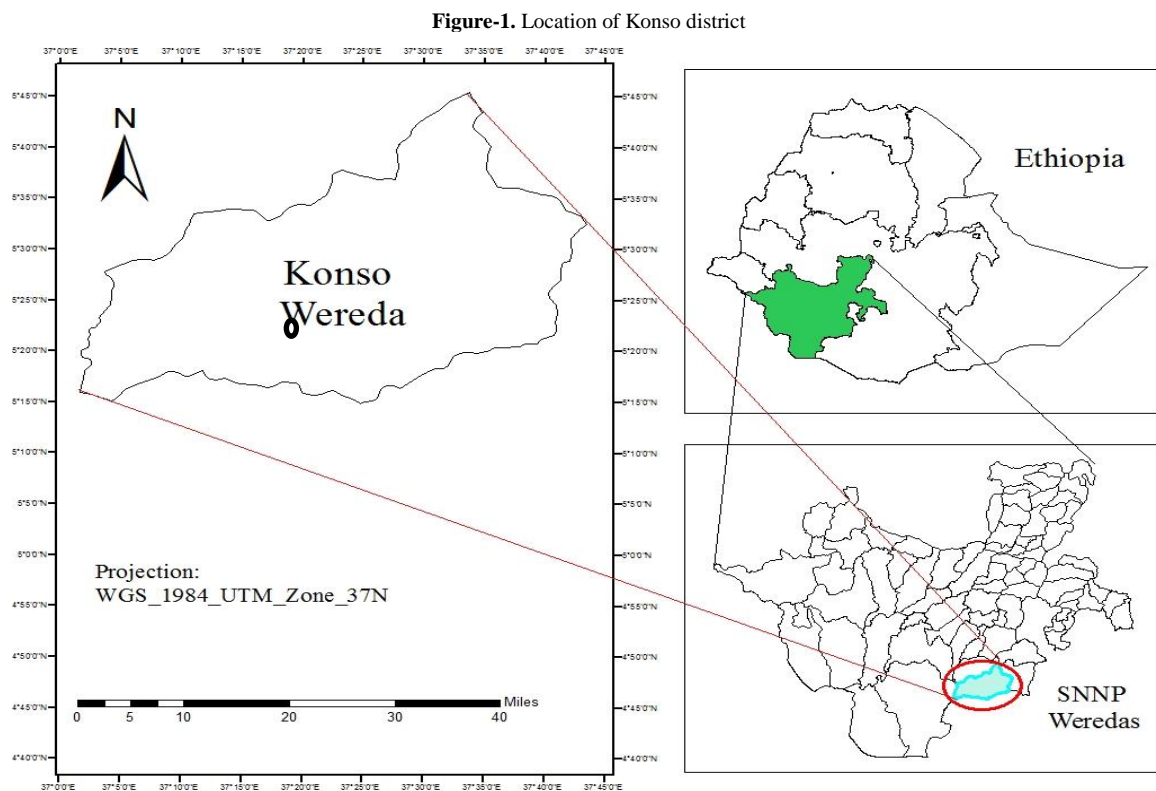
The altitude of Konso district varies from 500 m.a.s.l to 2000 m.a.s.l. Based on information obtained from the Konso District agricultural office, the main agro-ecological divisions of Konso accounts, about 70% arid (*Kola*) and 30% tropical sub-humid (*Woinadega*). The mean annual temperature of the District ranges between 17.6-27.50ºC. The average total annual rainfall is 550 mm; the temperature of the area is mostly hot and warm. There are two cropping seasons in Konso: Belg (February-May) accounting for 65-75% of the annual crop production and Meher (*Hagaya*) cropping season. The most common crops are cereals mainly sorghum followed by maize [7]. The climate of the Konso district is most favorable for the cultivation of a wide variety of crops like sorghum, maize, teff, wheat, barley, bean, pea, oil seeds (sesame), vegetable and fruit.

2.2. Types of Data, Sources and Data Collection Methods
For this study, relevant data were collected from both primary and secondary data sources, which are of qualitative and quantitative nature. Primary data were collected from sample households using questionnaires, focus group discussions and key informants interview. Secondary data were collected from both published and

unpublished sources which include data on agricultural production, farming systems and other baseline information. The information was collected from regional, zonal and district-level offices of agriculture and rural development, and concerned government and non-governmental institutions.

2.3. Sampling Technique

A combination of both purposive and random sampling techniques were employed to draw an appropriate sample. Konso district was purposively selected for the study because of the presence of large number of sorghum producing households and its extent of production in the area. Konso district actually comprises of 41 rural *kebeles*. From these, 35 *kebeles* are major sorghum producers. In the first stage, out of 35 *kebeles,* five *kebeles* were selected randomly. In the second stage, based on the list of households of the *kebeles*, 124 sample farm households were selected from the total households of five *kebeles* by using formula developed by Yamane [8]:-

$$n = \frac{N}{1 + N(e)^2} = \frac{276985}{1 + 276985(0.09)^2} = 124 \text{ Households} \tag{7}$$

Where: n is the sample size needed, *N* is the total population and e is the desired level of precision. Finally, a total of 124 sample households was selected for interview as presented in Table 1 below.

Table-1. Kebele, number of households, and sample size selected from sample Kebeles

Kebele	Sorghum producing households	Sample size	Percent
Debana	1812	41	33
Mechekie	757	17	14
Borqara	1560	35	28
Gamolie	512	11	9
Arfaidie	898	20	16
Total	5539	124	100

Source: Own sampling design, 2015

2.4. Methods of Data Analysis
2.4.1. Descriptive Statistics

Mean, standard deviation, frequency, percentage and inferential statistical tests like chi-square test for potential discrete (dummy) explanatory variables and t-test was used to test the significance of the mean difference of continuous variables for the sample households.

2.4.2. Econometric Models
2.4.2.1. Specification of the Functional Form

The study used the stochastic frontier functional approach, which requires the priori specification of the production function to estimate the level of technical efficiency.

2.4.2.2. Estimation of the Empirical Model

The model parameters in stochastic production frontier were analyzed by employing a single stage estimation procedure. In using the two-stage estimation procedure of efficiency level and factors determining, the efficiency index is estimated by the stochastic production function in the first stage and then regressed against a number of other farm specific and socioeconomic variables in the second stage. The one-stage estimation procedure of the inefficiency effects model together with the production frontier function would be used in the study. The two-stage procedure produces inconsistency in the assumption [9]. Moreover one-stage procedure is the most commonly used method in the analysis of technical efficiency. Thus one-stage procedure is selected for this study.

Using Ordinary Least Squares (OLS) estimation procedure, it is possible to get consistent estimators for all the parameters in the model except the intercept term. But if we use the OLS method to estimate the intercept term it will be biased. This problem occurs due to the fact that the mean of (*v - u*) is not zero by assumption. However, a consistent estimator of the intercept can be formed by using Corrected Ordinary Least Squares (COLS), which involves adjusting the OLS intercept by the mean of *u*.

In addition to the COLS method, one can also adopt the more efficient maximum likelihood (ML) approach [10], which requires numerical maximization of the likelihood function. The ML estimation is asymptotically more efficient than the COLS estimator and empirical investigations suggested that the ML estimation is significantly better than the COLS estimator, when the contribution of the technical inefficiency effects to the total variance term is large [9].

In this study, ML estimation procedure is used to estimate the stochastic production function model described in equation (8). To use ML estimation procedure, the assumptions made about the distributions of the error components *u* and *v* should be respected [9]. It is assumed that u_is are independently and identically distributed half-normal random variables with mean zero and variance σu^2. While v_is are assumed to be independent and identically distributed normal random variables with mean zero and constant variance $\sigma^2 v$. ($v \sim (0, \sigma^2_v)$), independent of the u_is.

In most empirical applications the half normal distribution for the technical inefficiency effects (u_i) has been more frequently assumed.

Given a symmetric normal distribution for v_i and half normal distribution for u_i and by defining a parameter γ, which lies between zero and one and is equal to σ^2_u / σ^2_s, (where $\sigma^2_s = \sigma^2_u + \sigma^2_v$), Battese and Cora [11] showed that the log-likelihood function in terms of this parameterisation is equal to:

$$LnL(Y_i) = \frac{-N}{2}\ln(\frac{\pi\delta_s^2}{2}) + \sum_{i=1}^{N}\ln\Phi\left(\frac{-\varepsilon_i\lambda}{\delta_s}\right) - \frac{1}{2}\delta_s^2\sum_{i=1}^{N}\varepsilon_i^2 \qquad (8)$$

Where, $\varepsilon_i = V_i - U_i = \ln y_i - X^{'}_i\beta$ and $\lambda = \sqrt{\delta^2_u \big/ \delta^2_v}$

$\Phi(.)$= Is the distribution function of the standard normal random variable.

$\ln L(Y_i)$ = logged output level for the ith farm

$X^{'}_i$ = logarithm of the level of input for the ith farm

β = Regression coefficient

λ = Discrepancy parameter as defined above

σ_s^2 = variance of standard error of the composed error term and N = number of observations

The ML estimates of β, σ_s^2, and λ is obtained by finding the maximum of the loglikelihood function defined by equation (8). The ML estimators are consistent and asymptotically efficient [12].

Once the estimates of the model parameters are found, the results can be used to estimate the technical efficiency levels of each individual farm in the sample observation as well as the mean level of the technical efficiency of the total sample households. The ratio of the observed output for the ith farm, relative to the potential output, defined by the frontier function; given the input vector X_i is used to define the technical efficiency of the ith firm.

$$TE_i = \frac{Y_i}{\exp(X^{'}_i\beta + V_i)} = \frac{\exp(X^{'}_i\beta + V_i - U_i)}{\exp(X^{'}_i\beta + V_i)} = \exp(-U_i) \qquad (9)$$

Where, $Y_i = \exp(X^{'}_i\beta + V_i - U_i)$ is the stochastic frontier model for i^{th} household,

Y_i = denotes output of sorghum produced by the ith household,

$X^{'}_i$ = is $(1 \times k)$ row vector with the first element equal to 1, of input quantity used by the ith household for the production of sorghum,

$\beta = (\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \ ... \ \beta_k)$ is $(1 \times k)$ column vector of unknown parameters to be estimated,

U_i = is a non-negative random variable associated with technical inefficiency of the ith household for the sorghum production,

V_i = is random error term of the model which capture random shock of the production of sorghum in the ith household and i = 1, 2, 3, …, n is number of samples in a population.

For the frontier model defined by equation (8), the null hypothesis, that there are no technical inefficiency effects in the model is conducted by testing the null and alternative hypothesis H_0: $\gamma = 0$ versus H_1: $\gamma > 0$. The hypothesis involving γ are considered due to the fact that, the Battese and Cora [11] parameterisation was adopted for this study and the test must be performed as a one sided test because γ cannot take negative values. As a result the One-sided Generalized Likelihood ratio Test suggested by Coelli [13] should be performed when maximum likelihood estimation is involved. This test statistic requires the estimation of the model under both the null and alternative hypotheses. Under the null hypothesis H_0: $\gamma = 0$, the model is equivalent to the traditional average response function, without the technical inefficiency effect, U_i. The test statistic is calculated as:

$$LR = \lambda = -2\{Ln[L(H_0)/L(H_1)]\}$$
$$= -2\{Ln[L(H_0) - L(H_1)]\} \qquad (10)$$

Where: $L(H_0)$ = the log likelihood value of the null hypothesis;

$L(H_1)$ = the log likelihood value of the alternative hypothesis; Ln is the natural logarithms

In this case if H_0: $\gamma = 0$ is true the LR has asymptotic distribution which is a mixture of Chi-square distributions Coelli [13]. Then the critical value for the one-sided Generalized Likelihood ratio Test of H_0: $\gamma = 0$ versus H_1: $\gamma > 0$ can simply be calculated. The critical value for a test of size α is equal to the value, $\chi^2_1 (2\alpha)$, where this is the value exceeded by the χ^2_1 random variable with probability equal to 2α. Thus the one-sided generalized likelihood ratio test of size α is: "reject H_0: $\gamma = 0$ in favor of H_1: $\gamma > 0$ if LR exceeds, $\chi^2_1 (2\alpha)$.

As far as factors determining technical efficiency are concerned, farmers have different characteristics that make them attain different levels of technical efficiency. Given a particular technology to transform physical inputs in to outputs, some farmers are able to achieve maximum output while others are not. These, factors need to be identified in order to define the problem of inefficiency thereby investigated for remedial measures to solve the problem. Most of the time in the area of efficiency analysis the following variables are commonly used. Given the specified

explanatory variables below, the functional relationship between input and output used in the stochastic production function can be specified as follows:

$$Ln(OUTP) = f(AREA, UREA, DAP, OXD, HLAB, SEED, CHEM; \beta_i) + \varepsilon_i \qquad (11)$$

Where: Ln($OUTP$) = is the total output of sorghum obtained from the ith farm in quintal.
$AREA$ = the total size of land in hectare allocated for sorghum crop by the ith household.
$UREA$ = the total amount of urea fertilizer in kilogram applied by the ith household
DAP = the total amount of DAP fertilizer in kilogram applied by the ith household.
OXD = the total number of oxen days used by the ith household.
$HLAB$ = the total labor force (family and hired) which are all measured in terms of man-day.
$SEED$ = the total quantity of sorghum seed used by the ith household measured in kg.
$CHEM$ = Chemicals such as herbicides or pesticides used as an input particularly in sorghum due to serious weed, pest and disease attack by the ith household.
f ( ) = Appropriate functional form (e.g. Cobb-Douglas or Translog functional form)
β_i = vector of unknown parameters to be estimated, and ε_i = composed error term ,
Where: $\varepsilon_i = V_i - U_i$

U_i = non-negative random variable, independently and identically distributed as N(u_i, δ^2_u) which is intended to capture the technical inefficiency effects in the production of sorghum measured as the ratio of observed output to maximum feasible output of the ith farm and

V_i = a disturbance term independently and identically distributed as N (0, δ^2_v) which is intended to capture events or factors outside the control of the farmers.

The technical inefficiency effects model by Battese and Coelli [14] in which both the stochastic frontier and factors affecting inefficiency (inefficiency effect model) are estimated simultaneously is specified in Equation (12) as a joint estimation of a stochastic frontier production function:

$$LnOUTP = f\{\beta_0 + \beta_1 \ln AREA + \beta_2 \ln UREA + \beta_3 \ln DAP + \beta_4 \ln OXD + \beta_5 \ln HLAB +$$
$$\beta_6 \ln SEED + \beta_7 \ln CHEM + V_i - (\delta_0 + \delta_1 AGEHH + \delta_2 EDUCLVL + \delta_3 FAMSIZE + \delta_4$$
$$OFFOC + \delta_5 FRAGMENT + \delta_6 ACCTRAIN + \delta_7 EXTSERV + \delta_8 ACSCDT + \delta_9 LIVSTOCK$$
$$+ \delta_{10} DISTRES + \delta_{11} FERTILITY + \delta_{12} SLOP + \delta_{13} SEX + W_i\} \qquad (12)$$

Where: δ_i = Parameter vector associated with inefficiency effect to be estimated; w_i = Error term.

3. Results and Discussion
3.1. Input Variables used to Estimate the Production Function

The average sorghum yield produced by sample households was 12.82 quintal per ha, with a standard deviation of 7.94, maximum of 36 and minimum of 3 quintal per ha which is dependent variable in the production function (Table 2). In the study area, sorghum is produced two times per annum. The land allocated for sorghum production, by sample households during the survey period, ranges from 0.125 to 1.75 ha with average land size and standard deviation of 0.68 ha and 0.38 respectively.

In the study area, farmers use both Urea and DAP fertilizers for sorghum production. The average amount of Urea and DAP fertilizers applied in the production of sorghum by sample households were 42.43 Kg per hectare and 49.94 Kg per hectare, respectively during 2014/15 sorghum production season. There was high variation of fertilizer utilization (both urea and DAP) in sorghum production by sample households. Like other inputs human labour and oxen power inputs were also decisive in the study area. Sample households, on average, use 36.83 man days per ha of labour for the production of sorghum during 2014/15 production season. In the production process labor input is used for major farming activities such as land preparation, sowing, chemical applications and fertilizer applications and weeding and other activities.

For sorghum land preparation oxen power was used by the sample households. Field survey result showed that about 75% sample households use oxen power for ploughing their sorghum land, and this oxen power is computed to oxen days. The average oxen power used by sample households was 11.44 oxen days per ha with standard deviations of 5.20. The other very important variable, out of which production is impossible, is seed. The amount of seed sample households' used was 19.98 Kg, on average with standard deviation of 8.15 (Table 2). There are different sorghum seed varieties used by households in the study area. Households used broadcasting method of sowing and on average the seed rate was 19.98 kg/ha which is greater than the recommended rate of 12 kg/ha for the study area. On average, sample households applied 0.32 liter of chemicals such as herbicides or pesticides per hectare in the study area for the protection of sorghum farms during 2014/15 production year.

Table-2. Output and input variables used to estimate the production function

Variable description	Summary statistics			
	Mean	St. deviation	Max.	Min
Sorghum output (Qt/Ha)	12.82	7.94	36	3
Land (Ha)	0.680	0.38	1.75	0.125
Seed (kg/Ha)	19.98	8.15	34	4
Human labor (MDs/Ha)	36.83	10.26	61	14
Oxen power (ODs/Ha)	11.44	5.20	27	4
DAP (Kg/Ha)	49.94	42.11	100	45
Urea (Kg/Ha)	42.43	41.37	98	50
Chemicals (Lit/Ha)	0.32	0.45	1.75	0.15

Source: Own computation result, 2015

3.2. Econometric Model Outputs
3.2.1. Test of Hypothesis

Before discussing the model output, let us begin with likelihood ratio (LR) tests to assess various assumptions related to the model specification. Tests of hypotheses for the parameters of the frontier model were conducted using the generalized likelihood ratio statistics. Accordingly four hypotheses were tested, to select the correct functional form for the given data set, for the existence of inefficiency, for variables that explain the difference in efficiency, and finally to identify type of distributions.

Table-3. Generalized likelihood ratio tests of hypothesis for the parameters of the SPF

Null hypothesis	LH_0	LH_1	Calculated χ^2 (LR) value	Critical χ^2 value	Decision
$H_0: = \beta_{ij} = 0$	-25.92	-15.84	20.19	41.34	Accept
$H_0: \gamma = 0$					Reject H_0
$H_0: = \delta_1 = \ldots \delta_{13} = 0$	-61.52	-25.92	71.20	22.36	Reject H_0
$H_0: = \mu = 0$	-61.52	-61.49	0.06	2.71	Accept

Source: Own computation result, 2015

The first test was the null hypothesis that identifies an appropriate functional form between restrictive Cobb Douglas and the non-restrictive Translog production function which specifies that square and cross terms are equivalent to zero. The Cobb-Douglas and the Translog functional forms are the most commonly used stochastic frontier functions in the analysis of technical efficiency in production. The Translog frontier function turns into Cobb-Douglas when all the square and interaction terms in the translog are zero. In order to choose between the two alternative functional forms that can better fit to the survey data collected, the null hypothesis that all the interaction and square terms are all equal to zero ($H_0 : \beta_{ij} = 0$), *i.e.* Cobb-Douglas frontier functional specification, is tested against the alternative hypothesis that these coefficients are different from zero ($H_1 : \beta_{ij} \neq 0$).

The test is made based on the value of likelihood ratio (LR) statistics, which can be computed from the log likelihood value obtained from estimation of Cobb-Douglas and Translog functional specifications using Equation (7). Then, this computed value is compared with the upper 5% critical value of the χ^2 at the degree of freedom equals to the difference between the numbers of explanatory variables used in the two functional forms (in this case df = 28). For the sample respondents, the estimated log likelihood values of the Cobb-Douglas and Translog production functions were -25.92 and -15.84, respectively. The computed value of likelihood ratio (LR = -2(15.84 – 25.92) = 20.19 is lower than the upper 5% critical value of the χ^2 with its respective degree of freedom (Table 3). Thus, the null hypothesis that all coefficients of the square and interaction terms in Translog specification are equal to zero was not rejected. This implies that the Cobb-Douglas functional form adequately represents the data.

The second null hypothesis was $H_0: \gamma = 0$, which specifies that the inefficiency effects in the SPF were not stochastic i.e. sorghum producing farms are efficient and have no room for efficiency improvement. After the appropriate production function is selected, the next step is a test for adequacy of representing the data using SPF over the traditional mean response function, OLS. The null hypothesis, $H_0: \gamma = 0$, which specifies that the inefficiency effects are absent from the model (that is all sorghum producers are fully efficient). Whereas, the alternative hypothesis, $H_1: \gamma > 0$, states that there is inefficiency in production of sorghum in the study area. Since this study is using the STATA version 12.1 computer programs, after fitting the function with the required defined variables the computer output displays results which include the test of null hypothesis about inefficiency component. From this computer program output it is found that, log likelihood value = 25.92, (chibar^2 (01)-value = 7.11 and p = 0.004). Hereafter, the decision of null hypotheses $H_0: \gamma = 0$, which specifies that the inefficiency effects are absent from the model is rejected at 1% level of significance for the sampled households.

The coefficient for the discrepancy ratio (γ) could be interpreted in such a way that about 90 percent of the variability in sorghum output in the study area was attributable to technical inefficiency effect, while the remaining 10 percent variation in output was due to the effect of random noise. This implies presence of scope for improving output of sorghum by first identifying those institutional, socioeconomic and farm specific factors causing this variation. Therefore this data can be better represented by the stochastic production frontier than the average response function. The null hypothesis was rejected (Table 3). This implies the traditional average production

function does not adequately represent the data. Therefore, the inclusion of the technical inefficiency term is an important issue to the model.

The third null hypothesis that the explanatory variables associated with inefficiency effects are all zero (H_0: $\delta_1 = \delta_2 \ldots = \delta_{13} = 0$) was also tested. To test this hypothesis likewise, LR (the inefficiency effect) was calculated using the value of the Log-Likelihood function under the stochastic production function model (a model without explanatory variables of inefficiency effects: H_0) and the full frontier model (a model with explanatory variables that are supposed to determine inefficiency of each: H_1). For the sample households, the calculated value $\lambda_{LR} = -2(25.92 - 61.52) = 71.20$ is greater than the critical value of 22.36 at 13 degree of freedom (Table 3) the value of LR implying that, the null hypothesis (H_0) that explanatory variables are simultaneously equal to zero was rejected at 5% significance level. Hence, these variables simultaneously explain the sources of efficiency differences among sample farmers in the study area. Thus the observed inefficiency among the sorghum farmers in Konso district could be attributed to the variables specified in the model and the variables exercised a significant role in explaining the observed inefficiency. Therefore, the result confirms as the null hypothesis was rejected, implying that there is at least one variable that explain the difference in efficiency.

The fourth test conducted was, given such functional forms for the sample households; it was considered whether the technical efficiency levels were better estimated using a half normal or a truncated normal distribution of μ_i The results indicated that the half normal distribution was appropriate for the sample households in the study area as the calculated LR ratio value of 0.06 was less than the critical χ^2-value of 2.71 at 5% significance level. That means the null hypothesis (H_0: $\mu=0$ distribution assumption) was accepted at 5% significance level.

3.3. Estimation of Parameters of Production Function Model

Individual technical efficiency levels in sorghum production were estimated using the stochastic frontier production function. The input variables used in the stochastic frontier production model were Land allocated for sorghum (ha), chemical fertilizer (Urea and DAP) in kg, oxen power (ODs), Human labour (MDs), Quantity of seed (kg) and chemicals (herbicides or pesticides). The coefficients of the input variables were estimated under the full frontier production function (MLE). (Table 6). The maximum likelihood estimation for the best practice households, the output elasticity with respect to all the selected variables has the expected sign. That means all input variables entered in the production frontier function have been found positive sign of estimated coefficients that generally confirm to prior expectations. The result of the Cobb-Douglas stochastic production frontier showed that land allocated for sorghum, chemical fertilizer (Urea and DAP), oxen power, human labour and chemicals (herbicide or pesticides) inputs were found to positively and significantly (at 1% significance level except oxen power which is at 5% level of significance) explained the level of efficiency of sorghum production (Table 4), which are important variables in shifting the frontier output to the right. This indicated that at each and every unit of these variables there is a possibility to increase the level of output. But the mount of seed is insignificant.

Table-4. Maximum likelihood estimate of stochastic production frontier model

Variables	Parameters	Coefficients	Std. Err.	Z-value
Constant	β_0	1.297***	0.364	3.56
Ln(LAND)	β_1	0.1896***	0.042	4.54
Ln(UREA)	β_2	0.075***	0.0145	5.18
Ln(DAP)	β_3	0.0349***	0.0131	2.67
Ln(OXD)	β_4	0.1318**	0.056	2.35
Ln(HLAB)	β_5	0.2238***	0.0847	2.64
Ln(SEED)	β_6	0.0904	0.0550	1.64
Ln(CHEM)	β_7	0.1409***	0.0399	3.53
Sigma- square	δ^2	0.399***	0.088	
Gamma	γ	0.899***		
Lambda	λ	2.98***		
Log likelihood function		-25.92		
Returns to scale		0.887		

*, **, ***, Significant at 10%, 5% and 1% level of significance
Source: Model output, 2015

One of the appealing features of the Cobb-Douglas functional form is the direct interpretation of its parametric coefficients as a partial elasticity of production with respect to the input used. This attribute allows one to evaluate the potential effects of changes in the amount of each input on the output. The variables land allocated for sorghum, oxen power, human labour and chemicals are the main inputs in determining the output level of sorghum for sample households in the study area. Whereas, the elasticity of fertilizer (urea and DAP) are very low implying that these have less effect in determining the output level at the best practice (the maximum technical efficiency score). The positive coefficients of inputs indicate a 1% increase in land allocated for sorghum, urea, DAP fertilizer, oxen power, human labour and herbicides or pesticides yields 0.189%, 0.075%, 0.035%, 0.132%, 0.224% and 0.141% increase in sorghum output, respectively. In other words, if all the inputs are increased by 1%, sorghum output would increase by 0.887% (Table 4). Labor input used for sorghum production was found to be statistically significant and with expected sign for sample households. Hence, there may be shortage of labor during sorghum

production. That means there is overlapping of activities with other crops usually happened and shared the available labors. So, in this case labor would be the important variable in determining sorghum output level in the study area. Since the major concern of this study is to know the level of technical efficiency of sorghum growing households and the major factors determining the technical efficiency differentials in the study area, in-depth discussions on the structure of production function and coefficients of input variables is not required as such. The maximum-likelihood parameter estimates of the model show the relative importance of individual inputs and their aggregate significance in the production process as well as being useful in predicting the level of individual household's TE.

The diagnostic statistics of inefficiency component reveals that sigma squared (δ^2) was statistically significant at 1%, which indicates goodness of fit, and the correctness of the distributional form assumed for the composite error term. According to the model result of stochastic production function (Table 6) the value of λ is 2.98. The presence or absence of technical inefficiency was tested in the study using the important parameter of log likelihood in the half normal model λ = σu/σv. if λ = 0 there were no effects of technical inefficiency, and all deviations from the frontier were due to noise as stated in Aigner, et al. [15], the estimated value of λ = 2.98 significantly different from zero. The null hypothesis that there is no inefficiency effect was rejected at 5% level of significance, suggesting the existence of inefficiency effects for households in Konso district. Another important result in the analysis is the variance ratio parameter γ which found to be significant at 1% level expressing that about 90% of sorghum output deviations are caused by differences in farm level technical efficiency as opposed to the random variability that are outside their control of the producers.

Returns to scale is the sum of elasticities of Cobb-Douglas frontier production function with respect to all inputs used, reflects the degree to which a proportional increase in all the inputs increase output. The sum of elasticity $\Sigma\beta$ as presented in Table 6 is 0.89 which implies decreasing returns to scale such that when all inputs specified in the model for the production of sorghum are increased by 1 unit, output will in turn increase by 0.89 units. Even though nonnegative and less than one value of the sum of elasticity imply that producers are operating in the stage two of the production process, they are not efficient in allocation of resource this implies production is inefficient moreover there is a room to increase production with a decreasing rate.

3.2.4. Technical Efficiency Scores of Sample Households

The results of the efficiency scores indicated that there were wide ranges of differences in technical efficiency among sorghum producer households in the study area. The mean technical efficiency of sampled households during the survey period was 68.75%. The technical efficiency among households ranged from 21.29 to 96.28% (Table 5). This wide variation in household specific technical efficiency levels is consistent with study result reported by Betty [16], Ike and Inoni [17] and Berhan [18].

The mean level of efficiency found in this study was similar with other African countries. For instance, Alemu, et al. [19] found the mean technical efficiency of East Gojam of Ethiopia to be 75.68 percent, Rahman, et al. [20] found mean efficiency levels of about 69.6% among crop production in Lafia local government area of Nasarawa state, Nigeria while Oluwatayo, et al. [21] found mean efficiency levels of about 68% among Maize farmers in rural Nigeria.

Table-5. Summary statistics of estimated technical efficiencies of sample households

Description	Technical efficiency estimates
Maximum	0.9628
Minimum	0.2129
Mean	0.6875
Standard deviation	0.228
Skewness	-0.415

Source: Own computation result, 2015.

This shows that there is a wide disparity among sorghum producer households in their level of technical efficiency which may in turn indicate that there exists a room for improving the existing level of sorghum production through enhancing the level of household's technical efficiency. The mean level of technical efficiency further tells us that the level of sorghum output of the sample households can be increased by about 31% if appropriate measures are taken to improve the efficiency level of sorghum producing households. In other words, there is a possibility to increase yield of sorghum by about 31% using the resources at their disposal in an efficient manner without introducing any other improved (external) inputs and practices.

Table-6. Frequency distribution of the range of individual technical efficiency levels

Range of TE (%)	Frequency	Percent
<30	7	5.65
31-40	5	4.03
41-50	22	17.74
51-60	16	12.90
61-70	9	7.26
71-80	9	7.26
81-90	28	22.58

91-100	28	22.58
Total	124	100

Source: Own computation result, 2015.

It is observed that 47.58% of the sample households are operating below the overall mean level of technical efficiency while, 22.58% of the households are operating at the technical efficiency level of more than 90%. The distribution of the technical efficiency in table above clearly shows that the technical efficiency is skewed heavily in the 81 and 90 range, representing 45.16% of the sample farmers. The wide variation in technical efficiency estimates is an indication that most of the farmers are still using their resources inefficiently in the production process and there still exists a wide room for improving sorghum production through improving the current level of technical efficiency contrasting the Schultz's hypothesis [22]. This might imply that in the long run improving the existing level of technical efficiency of households alone may not lead to significant increment in the level of sorghum output.

3.2.5. Sources of Technical Inefficiency

Having the information about the existence of technical inefficiency and measuring its magnitude, examining the major factors causing this inefficiency level is the next most important step of the study. About 13 socio-economic and institutional variables were hypothesized to affect level of technical inefficiency of sorghum growing households in the study area, out of which eight of them were dummy variables and the remaining were continuous variables. Most of the variables were discussed in the descriptive result section above. Hence, here we discuss only some of the variables in the inefficiency model. The driving force behind measuring households' efficiency in sorghum production is to identify important variables or determinants to generate information in order to make an intervention and improve the existing level of efficiency. The parameters of the various hypothesized variables in the technical inefficiency effect model that are expected to determine efficiency differences among households were estimated through MLE method using one-stage estimation procedure. The determinants of technical inefficiency in a given period vary considerably depending on the socio-economic conditions of the study area particularly pertaining to managerial characteristics and other related factors.

Table 7 shows the result of the technical inefficiency model estimates. Before discussing the significant determinants of inefficiency in sorghum production it is important to see how efficiency and inefficiency are interpreted. The result in Table 7 is presented in terms of inefficiency and hence the negative sign shows the increase in the value of the variable attached to the coefficient means the variable negatively contribute to inefficiency level or conversely it contributes positively to efficiency levels. Thus, any negative coefficient happens to reduce inefficiency which implies its positive effect in increasing or improving the efficiency of the farm and vice versa. The coefficients of those socio-economic and institutional variables included in the model were estimated simultaneously by the ML procedure using the estimated level of technical efficiency as dependent variable. One important point to be considered is that the dependent variable is the inefficiency component of the total error term estimated in combination with the production frontier.

Table-7. Maximum likelihood estimates of the factors determining technical inefficiency

Variables	Coefficient	Std. Err	z-value
Constant	-1.855	1.247	-1.49
Age	0.035**	0.015	2.37
Education	-0.721*	0.425	-1.70
Family size	-0.158**	0.081	-1.96
Off-farm occupation	-0.602*	0.357	-1.69
Land fragmentation	-0.089	0.130	-0.69
Access to training	-0.550	0.405	-1.36
Extension service	-0.902**	0.404	-2.23
Access to credit	-0.134	0.409	-0.33
Livestock holding	0.101**	0.052	1.96
Plots distance	0.364***	0.137	2.66
Soil fertility status	-0.705*	0.367	-1.92
Slope of farm land	-0.410	0.492	-0.83
Sex of the household head	-0.107	0.396	-0.27

*, **, ***, Significant at 10%, 5% and 1%, level of significance.
Source: Model output, 2015.

The results of the inefficiency model shows that, among thirteen variables used in the analysis, age, education level of household head, family size, off/non-farm activities, extension contact, livestock holding, plots distance from household's residence and soil fertility status were significantly contributing to technical inefficiency of sorghum growing households. (Table 7). The following sections are dedicated for the discussions on the implications of those variables significantly contributing to technical inefficiency.

Age: In the study area, the mean age of the sample households was 42 years. Age of the households can have direct relationship with experience in farming as well as capacity to work on those laborious farming activities. But, the technical inefficiency model result indicated that the coefficients of age for sample households, was statistically

significant at 5% significance level and have positive sign. This implies that an increase in age of the household head is associated with increases in technical inefficiency model. This can be explained by the fact that as a household head becomes more aged in life, it becomes practically difficult if not impossible for him/her to take proper utilization of inputs and adoption of new technologies on their farms and therefore becoming more inefficient. The result is consistent with findings of Kinde [23] and Hailemaraim [24]. But the result of this study contradicts Getachew and Bamlaku [22] and Mohammednur and Negash [25] which argued that farmers at older age may accumulate good command of resources like labor, oxen and farm tools that could enhance their efficiency, since better availability of farm resources enhances timely application of inputs in crop production that enhance efficiency of the farm.

Educational status of the household head: Education level of farmers is a factor that the literature frequently relates to technical efficiency. It is believed to enhance the managerial and technical skills of households. The coefficient of education status is estimated to be negative as expected and statistically significant at 10 per cent level for sorghum farmers which indicate that farmers with greater years of formal education tend to be more efficient technically in sorghum production probably due to their enhanced ability to acquire technical knowledge, which make them produce closer to the frontier output. According to Battese and Coelli [14], education is hypothesized to increase the household's ability to utilize existing technologies and attain higher efficiency levels. Several other studies also indicated that education being associated with efficient management of production systems and hence higher efficiency levels like studies of Ahmed, et al. [26], Assefa and Tadele [27], Hailemaraim [24], Wondimu and Hassen [28], [29]. This could be argued that access to better education enables households to better manage their resources in order to sustain the environment and produce at optimum levels. The results of this analysis show that education level negatively and significantly affecting inefficiency. This indicates that, education capacitating in human capital that enhances the productivity of households since they will be better able to allocate homemade and purchased inputs, select the appropriate quantities of purchased inputs and choose among available techniques.

Family size: It is plausible that the household with more members can perform farming activities on time. Crop production is labor-intensive activity in Ethiopia. In this regard, the effect of household size on technical inefficiency cannot be overemphasized. In fact, the literature offers mixed results. On the one hand, people argue that an increase in the number of family members could decrease technical inefficiency if it results in increased labor allocated to crop production. The coefficient of family size in the technical inefficiency model is negative and significant at 5% significance level. The result is similar to the expectation that those households having large family size are less inefficient than households having small family size, because; family labor is the main input in crop production. As the households has large family size, he/she would manage crop plots on time and may be able to use appropriate input combinations. The result is consistent with the findings of Abdulai and Eberlin [30], Essa [31] and Ahmed, et al. [26] but inconsistent with the findings of Fekadu [32], Mekdes [33], Endalkachew [34] and Hailemaraim [24].

Off/non-farm activities: Off/non-farm activities refers to the opportunity that the farm households had to work outside their own farm operations. A number of studies conducted revealed that off/non-farm activities have a systematic effect on the technical inefficiency of the households. It will have a negative relation with the technical efficiency if the farmer is always out of the farming activity for the search of additional income from these off/nonfarm activities. On the other hand, incomes from off/ non-farm activities may be used as extra cash to buy agricultural inputs and can also improve risk management capacity of households. Off/non-farm activities can directly link with the timely availability of family labor for on-farm operations. That means, the time at which some portion of the family labor is diverted towards off/non-farm works can delay farm activities. On the other hand, it will affect the technical efficiency positively for the reason that the income obtained from such off/non- farm activities could be used for the purchase of agricultural inputs, and augment financing of household expenditures which would otherwise, put pressure on on-farm income [22]. But in this study it was hypothesized that there is efficiency differential among households who are engaged in off/non-farm and those who are not. The result of this study showed that the coefficients of the variable entered into the technical inefficiency effect model indicated that the variable affects the level of technical inefficiency negatively and significantly. In other words, those households engaged in some off/non-farm activities are less technically inefficient relative to those who were not engaged in activities other than their farm operations.

The possible explanation is that it would assist the households to supplement other costs associated with their living, perhaps. It may have affected technical inefficiency negatively for the reason that the income obtained from such off/non-farm activities could be used for the purchase of agricultural inputs, and augment financing of household expenditures which would otherwise, put pressure on on-farm income. Therefore, there is significant difference in technical inefficiency between the sample households who participate in off/non-farm activity and who are not in sorghum production in the study area. The finding of this study is consistent to the findings of Gebreegziabher, et al. [35], Alemu, et al. [19], Dolisca and Jolly [36], Kinde [23], Haileselassie [37] and Hailemaraim [24]. Nevertheless it is contradictory with the findings of Khairo and Battese [38] Wondimu and Hassen [28] and Getachew and Bamlaku [22] who argue that presumably farmers having greater off-farm income might be more efficient as they gain experience because off-farm income might be a proxy for agricultural credit.

Extension contact: The theoretical justification for considering agricultural extension in technical efficiency studies is due to its effect on the acquisition of information. Increased agricultural extension activities are expected to increase farmers technical efficiency by lowering farmers cost of information. Consultation given by extension agents improves productivity of households. The output of inefficiency model also revealed that extension service utilization has negative sign and is significant at 10% significance level, suggesting that such contact increases farm efficiency because farmers are able to use modern techniques of sorghum farming

involving land preparation, planting, application of agro-chemicals (for example, fertilizer) and harvesting. The explanation is that farmers who have adequate extension contact avail themselves of modern agricultural technology for input mobilization, input use and disease control, which enables them to reduce technical inefficiency. Thus increasing the frequency of development agent visits is of paramount importance to provide effective agricultural extension services in the area. This indicates that the more the household had extension visit, the less he/she will become inefficient. Thus, this result shows that consultation of extension agents increase sorghum production by decreasing level of technical inefficiency. This implies that a frequent contact facilitates the flow of new ideas between the extension agent and the household thereby giving a room for improvement in farm efficiency. Advisory service rendered to the households in general can help households to improve their average performance in the overall farming operation as the service widens the household's knowledge with regard to the use of improved agricultural inputs and agricultural technologies. This result is in line with the results of Fekadu [32], Abebe [39], Musa [40] and Hailemaraim [24]. Contrary to this, Jema [41] found positive relationship between level of inefficiency and extension service.

Livestock holding: Number of livestock the households have in terms of tropical livestock unit was hypothesized to have negative influence in the inefficiency model. That means households who have better livestock holding are less inefficient than others. However, the finding shows that, the coefficient is positive and significant at 5% level of significance indicating that household with higher livestock holding are more inefficient than those who have less livestock size. Livestock in a mixed crop-livestock farming system have two fold importance in that, it supply oxen power (draught power) for ploughing and threshing, provide manure that will be used to maintain soil fertility and it serves as shock absorber to an unexpected hazard in crop failure as sources of food and income (cash) for the family. Timely ploughing and threshing is decisive in the production of crops thus access of livestock is important to better production. Since all types of animals and poultry production are considered in this study, livestock competitive effect has dominated its supplementary effect. This result is in line with the results of Fekadu [32], Assefa and Tadele [27], Wondimu and Hassen [28] and Hassen [42].

Plots distance from household's residence: The result showed that the variable had positive sign and significant effect on technical inefficiency at 1% level as expected. This implied that there is positive relationship between plots distance from household's residence in sorghum production and technical inefficiency (i.e., as the distance increases, technical inefficiency increases). Therefore, households whose farm plot is far from residence are more inefficient than those located at relatively near to farm plot. There is also significant mean technical efficiency difference between the nearest and the farthest farm plots from household's residence at 1% level of significance. This could be attributed to the fact that the farther the farm land or farm plot from the respondent's residence, the greater would be the cost of transport, management, supervision and opportunity cost. This in turn may hinder the optimal application of farm inputs and led to technical inefficiency. The result is consistent with findings of Alemayehu [43].

Fertility status of soil: It was hypothesized that the fertility status of the land to have significant impact on the level of inefficiency in sorghum production. The result indicates that the coefficient of soil fertility status is negative and significant at 10% level of significance. This implies that, fertility of land is an important factor in influencing the level of inefficiency in the production of sorghum or positively contributes to technical efficiency of sorghum. Though in the short run, this value is out of the command of the household, it is possible to improve the fertility status by applying improved land management or soil conservation practices in the long run. Therefore, development programs in improving and maintaining the fertility of land will have positive impact in reducing inefficiency. This implies that households who allocated land which was relatively fertile were better in technical efficiency. Therefore, decline in soil fertility could be taken as cause for significant productivity difference. The result is in line with the arguments of Fekadu [32], Alemayehu [43], Mustefa [44] and Hailemaraim [24].

4. Conclusion

This study was conducted to analyze technical efficiency of smallholder farmers and identify factors contributing to technical inefficiency of sorghum production in Konso district of Southern Ethiopia from a total of 124 households using both Purposive and random sampling technique by using both descriptive statistics and econometric model. The estimated stochastic production frontier model indicated that land allocated for sorghum, fertilizer (Urea and DAP), oxen power, human labour and chemicals (herbicides or pesticides) were significant determinants of sorghum production. The significant coefficients of these parameters indicate that the increased use of this input can increase the output of sorghum to a higher extent at the existing technology in the study area. Therefore timely availability of this input is crucial. The analysis also revealed that the sum of the partial output elasticity's with the respective inputs is 0.89. This result indicates that production structure was characterized by decreasing returns to scale. That means a proportional increase in all the factors of production leads to the smaller proportional increase in output. Therefore, it is suggested that production of agriculture particularly sorghum be increased with using new recommended technologies and improved varieties and agricultural support services be made available to all households particularly the same households in order to increase the total production.

The discrepancy ratio, γ, which measures the relative deviation of output from the frontier level due to inefficiency, was about 90%. The mean technical efficiency level of households in sorghum production was 0.69, ranging from 0.21 to 0.96. This implies existence of efficiency differentials among households in the study area. Sorghum production can be increased by 31% by the capacity of those households who grow sorghum through efficient use of the available resources, given the current state of technologies. This will shifts the production frontier of smallholder households outwards. Thus, the existing level of output could be increased by reallocation of the

existing resources. Therefore, existence of inefficiency shows there is a room to increase the output of sorghum by improving the use of existing technologies by all households without introducing new technology. Smallholder households growing sorghum are not technically efficient and therefore there is allowance of efficiency improvement by addressing some important policy variables influenced households' level of technical inefficiency in the study area.

The estimated SPF model together with the inefficiency parameters show that age of the household head, educational level, family size, off/non-farm activities, extension contact, livestock holding, plots distance from household's residence and fertility status of the soil were found to be the major significant determinants of technical inefficiency level of households in sorghum production. The negative coefficients of education, family size, extension contact, off/non-farm activities and soil fertility status means these factors are significantly and negatively affected inefficiency of the households in the area. While, the positive coefficients of age and livestock holding and plots distance indicate that these factors affected inefficiency positively.

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