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Determinants of Technical Efficiency in Maize Production: The Case of Smallholder Farmers in Dhidhessa District of Illuababora Zone, Ethiopia

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Abstract
This study was conducted in Dhidhessa district of Illuababora zone in Ethiopia to measure the level of technical efficiency and identify its determinants in maize crop. A multi-stage sampling technique was employed to select 162 maize growing sample households. Inferential statistics and stochastic production functions were employed to achieve and interpret the result pertaining to objectives of the study. The Stochastic Production Frontier (SPF) result revealed that area allocated under maize and chemical fertilizers were appeared to be significantly influencing maize production at 1 percent probability level. The estimated gamma parameters indicated that 73% of the total variation in maize output was due to technical inefficiency. The average technical efficiency was 86% while return to scale (RTS) was 0.96 %.Based on the results, it was concluded that there existed scope for increasing maize output by 14 percent through efficient use of existing resources on the sample households. By improving the efficiency of maize production even through efficient use of existing resources of the farmers, an additional output of 2060 quintals of maize could have been produced on 7550 hectares of land allocated under maize production during the study period in the district. Thus, ample scope existed to realize higher output with existing resources and level of production technology. The socio-economic variables that exercised important role for variations in technical efficiency were age, education, improved seed, training on maize production and labor availability in the household. Nevertheless, participation on off farm income, interaction of off farm income and education, distance to market, and number of livestock were found to decrease efficiency significantly among farm household. Therefore, innovative institutional arrangement, education and farmers training accompanied with more access to fertilizer and improved seed were likely to enhance production efficiency in the study area.
Keywords: Technical efficiency, maize production, Stochastic Frontier, Dhidhessa district

1. INTRODUCTION

Maize was originated in Central America and introduced to West Africa in the early16th Century (FAO,1992) and to Ethiopia between the 16th and the 17th (McCann, 2005). It is Africa's second most important food crop, after cassava, and is grown in a wide range of environments. Per capita consumption of maize in Africa is highest in eastern and southern Africa. Maize is processed to offer various product ranges, which include whole maize meal flour, sifted maize meal, vegetable oil, flour for confectionery, dough, corn flakes, snacks and crackers, starch converted to process sugars like glucose syrup and dextrose (Noah,2005).

Maize is one of the cereal crop produced in most part of Ethiopia. In 2007/08, maize production was 42 million qt, 40 percent higher than teff and 75 percent higher than wheat production. With an average yield of 17.4 qt per hectare (equal to 32 million qt grown over 1.8 million hectares) from 1995 to 2008, maize has been the leading cereal crop in Ethiopia since the mid-1990s in terms of both crop yield and production (Rashid eta.l, 2010). In the year 2008/09, cereals contributed 84.69% (about 144.96 million qt) of the grain production in Ethiopia. From which maize, wheat, teff and sorghum made up 22.97% (39.32million qt), 14.83% (25.37 million qt), 17.69% (30.28 million qt) and 16.38% (28.04 million qt) of the grain production, respectively. The average yield of cereals namely maize, wheat and teff were 22.24, 17.46 and 12.22 qt per hectare, respectively (CSA, 2009). Moreover the survey made by international food policy research, indicated that in Oromiya region, average maize yields were 70% higher when improved seed and fertilizer were used as compared to the local seed without fertilizer. It indicates the existence of more than 40% yield potential for further improvement based on results from research stations (Xinshen Diao, 2010).

According to CSA (2009) in Illuababora zone, 208,516.9 ha of land allocated for cereal crop cultivation out of which 77,179.78 ha (37%) was covered by maize alone. In this zone the total production of maize reached 1.75 million qt with an average yield of 22.71 qt per ha as compared to the regional average of 23.33 qt per ha. In Dhidhessa district the average yield of maize was less than the zonal average though more proportion of land was allocated for maize relative to the other cereal crops.

With 2.9% population increases, people are being pushed to new lands and many into marginal lands. One of the enormous challenges in the drive to increase food to feed the growing population will be to raise productivity and efficiency in the agricultural sector (CSA, 2009). Hence the main motivation of efficiency and productivity studies were the need to investigate and understand the forces that drive maize productivity in order to analyze and recommend appropriate improvement measures.

As a result, examining the optimum utilization of the seeds, inorganic fertilizers and labor utilized with respect to productivity of maize could be considered as a one-step forward towards bridging the existing information gap. Specialty, the information generated would provide direction for the realization of the two national projects namely Agricultural Growth Program (AGP) and Capacity Building for Scaling up of Evidence Based Best Practices in Agriculture Production in Ethiopia (CASCAPE). In Dhidhesa woreda, the AGP is aimed primarily at increasing agricultural productivity, enhancing market performance and facilitating value addition in selected targeted areas while the CASCAPE project is designed to assist the activities deployed under AGP by further strengthening the capacity of AGP stakeholders in identifying, documenting and disseminating best practices in agricultural production. (CASCAPE, 2011; AGP, 2011).

Therefore, the aim of this study was to estimate the levels of technical efficiency and identify factors influencing levels of technical efficiency of smallholder maize producers in Dhidhessa district of Illubabor Zone. This has a paramount contribution to gain deep insight to understand challenges and constraints in maize production by indicating avenues for possible policy intervention towards improving maize productivity.

2. METHODOLOGY of the study

2.1 Description of the Study Area

This study was conducted in Dhidhessa district at Illubabor zone of Oromiya Regional state, Ethiopia. The district is surrounded by Gatira district in west, Gechi in the north and Gummay district in the south and Goma district in east. According to Dhidhessa district MoRD office, the district covers approximately an area of 73,855 ha. Moreover the Oromia livelihood zone report of 2007 indicated that the dominant agro ecology zone is midlands or woinadega while. the topography is predominantly plains with some gentle undulating slopes. The mean annual temperature is 20.7ºC and annual rainfall is one of the highest in the country receiving 1200-1700 mm per year. Rain fed agriculture is the main source of livelihood in the area. The soil is fertile loam soil with a potential possessing moderate productivity. The main rainy season, genna, lasts from end of April to October while arfasa lasts from January to April. Major food crops produced are maize, sorghum and teff while the common cash crops are coffee and chat. It is a major coffee producing area which supplies markets with export quality coffee. (Tefera et al.,2011).

2.2 Sampling Technique and Sample size

Multistage sampling technique was used to select the sample respondents. From Illuababora zone, Dhidhessa district was selected purposively based on accessibility for the study. There were 22 kebeles in Dhidhessa district where maize cultivation was carried on extensively. Out of these 22 maize producing kebeles, 4 kebeles were selected randomly. A complete list of all farmers growing maize along with their operational size of their landholding and area allocated under maize was prepared. Finally 162 farmers from four kebeles were randomly selected in probability proportion to number of farmers in each kebeles. Thus a three stage sampling technique was followed in selecting the sample households.(Appendix 1).

2.3. Data Collection

Primary and secondary data were collected. The data pertaining to output obtained and quantity of various inputs used in maize production were collected. These include output obtained per plot, the quantity of inputs such as human labor, oxen labor, quantity of seed and amount of fertilizer used. In addition, demographic, socio-economic and institutional data were collected from the sample respondents. Secondary data related to maize production were collected to clarify and support analysis and interpretation of primary data. Secondary data were also obtained from reports of similar studies and information's documented at various office levels of MoARD.

2.4 Method of Analysis

Descriptive and inferential statistics along with econometric models were used to analyze the data. Descriptive statistics such as mean, standard deviation, frequency and percentage were employed to analyze the data collected on socio-economic, institutional and agro ecological characteristics of the sample households. Inferential statistics such as t-test and chi-square(X2) tests were used to undertake statistical tests on different continuous and categorical data, respectively. The econometric analyses follow the following processes. In the first step, the data was checked for regression model assumption including outliers, multicollinearity and heteroscedasticity and model specification test. Finally, the data were analyzed using stochastic frontier approach by FRONTIR Version 4.1 (Coelli,1996a).

2.5 Stochastic frontier approach to measure efficiency

The theory and concept of measurement of technical efficiency has been linked to the use of production functions. Different techniques have been employed to either calculate (non-parametric) or estimate (parametric) the efficient frontiers. These techniques are classified as parametric and non-parametric methods. Farrell (1957) was the first to formulate a non-parametric frontier method to measure production (economic) efficiency of a firm. According to him, efficiency ratios are calculated from sample observations. He defined technical, allocative and economic efficiencies. Technical efficiency (TE) reflects the ability of a firm to obtain maximum output from a given resources.

The stochastic frontier production model was employed to analyze and measure technical efficiency by estimating a production function. The three production functions tested to estimate a frontier were Cobb-Douglas, Translog, and Quadratic production function. The stochastic frontier approach splits the deviation (error term) into two parts to accommodate factors which are purely random and are out of the control of the farmers. One component is the technical inefficiency of a firm and the other component is random shocks (white noise) such as bad weather, measurement error, bad luck, omission of variables and so on. The model was expressed as:

$$\ln Y_i = \beta_0 + \ln \sum \beta_i X_{ij} + \exp^{e_i} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where
ln -denotes the natural logarithm; i represents the ith farmer in the sample,
Yi -represents yield of maize output of the ith farmer (Qt/ha),
Xij -refers to the farm inputs of the ith farmer
ei= vi-ui which is the residual random term composed of two elements vi and ui.
The vi is a symmetric component and permits a random variation in output due to factors such as weather, omitted variables and other exogenous shocks.
The vis are assumed to be independently and identically distributed N (0,σ2v), independent of ui.. The other component, uis, is non-negative random variable and reflects the technical inefficiency relative to the stochastic frontier. The ui s are assumed to be independently and identically distributed as half-normal, u~|N (0, σ2v)|. The parameters β, σ2= σv2+σu2 and γ= σu2/ σ2 of the above stochastic production function can be estimated using maximum-likelihood method, which is consistent and asymptotically efficient (Aigner et al., 1977).

2.6 Production function variables

The technical efficiency of maize producer in Dhidhessa was measured by considering the output obtained per plot of the ith farmer as the dependent variable. The output of maize was measured in quintals during the 2011 production year. The independent variables were the inputs (factors) of production used in the same production year. Accordingly the relevant inputs considered and the variables that were used in the stochastic frontier model were defined as follows
Where:
Y - is the output of maize obtained from the ith plot (Qtl/ha);
X1-the number of draught (oxen) power used per plot measured in oxen days /ha
X2- the number of pre-harvest human labor days per plot (Man days/ha)
X3- the cost of maize seed used on the ith plot (Birr/ha) ;
X4 -the cost of fertilizer (Urea and DAP) used on the ith plot (Birr/ha);
X5- Area planted under maize for ith plot measured in hectare;
Ln-Natural logarithm
Functional Forms of stochastic frontier
The Cobb-Douglas form of stochastic frontier production was as follows

$$\ln Y = \alpha_0 + \sum_{j=0}^{5} \alpha_j \ln X_1 + \alpha_5 X_5 + V_1 - U_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

The second specification was the Translog model, which is given by stochastic frontier production

$$\ln Y = \alpha_0 + \sum_{j=0}^{5} \alpha_j \ln X_{j1} + 0.5 \sum_{j\le}^{5} \sum_{k}^{5} \alpha_{jk} \ln X_{j1} \ln X_{k1} + \alpha_5 X_{51} + 0.5 \sum_{j\le}^{5} \sum_{k}^{5} \alpha_{jk} \ln X_{j1} \ln X_{k1} + V_1 - U_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

The translog production function is supposed to be flexible functional form in production study. This functional form is preferred to others for its flexibility in providing approximation to any twice-differentiable function and for its ability to capture interaction among inputs. However, one of the short-comings of the Translog function is the problem of multicollinearity (Sankhayan, 1988).

As a special case of translog function, the Cobb-Douglas production function behaved properly in deriving the dual cost frontier and it's conveniences in estimation and interpretation of parameter estimates relative to other functional forms. Nevertheless, the Cobb-Douglas functional form imposes severe restriction on the technology by restricting the production elasticity to be constant and the elasticity of input substitution to be unity. On the other hand, the translog functional form imposes no restrictions upon returns to scale or substitution possibilities (Coelli et al., 1998).The third specification of the stochastic frontier model is the quadratic form, which is defined as:

$$LnY = \alpha_0 + \sum_{j=0}^{5} \alpha_j lnX_{ji} + 0.5 \sum_{j\leq}^{5} \sum_{k}^{5} \alpha_{jk} lnX_{ji} lnX_{ki} + V_i - U_i \ldots\ldots\ldots\ldots\ldots\ldots 4$$

The inefficiency model is estimated from the equation given below.

$$lnY = \alpha_0 + \sum_{m=1}^{12} \delta_m Z_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 5$$

The $\mathbf{Z_i}$ is the variable in the inefficiency variables

Returns to scale

Returns to scale is equal to the summation of the production elasticity of each input and has been defined in the following equation:

$$RTS = \sum_{j=0}^{5} b_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6$$

2.7 Variables included in the determinants of inefficiency model

The technical inefficiency (u_i) could be estimated by subtracting TE from unity. The function determining the technical inefficiency effect is defined in its general form as a linear function of socio-economic and management factors. It can be defined in the following equation:

$$u_i = \delta_0 + \sum_{k=1}^{12} \delta_k Z_{ik} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 7$$

Where, u_i is the technical inefficiency effect, δk is the coefficient of explanatory variables. The Zi variables represent the socio-economic characteristics of the farm explaining inefficiency and may not be functions of y. As a result the technical inefficiency could be explained by the following determinants:

Zi1 = Age of the household head (years); Z_{i2}= Education (number of years of schooling of the farmer); Zi3 = Improved seed (A dummy variable. It takes a value of 1 if yes, 0 otherwise); Zi4 = Off-farm income (A dummy variable. It takes a value of 1if yes, 0 otherwise); Zi5 = Training (A dummy variable. It takes a value of 1 if yes, 0 otherwise); Zi6=Land fragmentation (it include the total number of plots at different locations); Zi7 = Labor availability (Labor force availability is measured in man equivalent for farming in the household); Zi8= Distance to maize plot measured in km; Zi9 = Number of livestock measured by TLU; Zi10= Education and off farm income interaction; Zi11 = Distance to market Zi13 = Participation in off farm income and labor availability interaction.

3. Results and Discussion

3.1 Hypothesis testing and model robustness

Before estimation of technical efficiency and analysis of its determinants, the presence of multicollinearity in explanatory variables was examined. Moreover the parameter estimates of the production frontier and the validity of the model used for the analysis were investigated. The hypotheses were tested using the generalized Likelihood Ratio (LR). Generalized Likelihood ratio computation was defined as LR = −2 [ln LH0 – lnLH1]

Where

LR= Log likelihood ratio

LHo =Value of log likelihood of null hypothesis

LH1= Value of log likelihood of alternate hypothesis

m*=degree of freedom= number of restrictions= number of estimated inputs and inefficiency variables in the current model (alternate hypothesis) minus number of estimated inputs and inefficiency variables in the preceding model (null hypothesis).

The null hypothesis was rejected when LR(calculated X2 m*) > tabulated X2 m*. If the null hypothesis was true, the test statistic had approximately a X2 distribution or mixed X2 distribution with degrees of freedom equal to the difference between the number of parameters specified in the null hypothesis and alternative hypothesis. Moreover the Log-Likelihood ratio was used to test the null hypothesis that the inefficiency component of total error term is equal to zero ($\gamma = 0$) against the alternate hypothesis that the inefficiency component is greater than zero ($\gamma > 0$). Thus, the log likelihood ratio was calculated and compared with the critical value of X2 with one degree of freedom at 5% level of significance.

In summary, the following tests were carried out for testing the functional forms, inefficiency effects and determinants of coefficients for maize farmers in the study areas:

(1) Frontier model specification for the data is Cobb-Douglas production function.

That is H0 : C-D (β6 ……… β20=0) is an adequate representation of the production function.

H11: Translog production function is adequate representation of the production function. Here β6 ……… β20 represents quadratic and interaction terms of Translog production function

(2) Frontier model specification for the data is Cobb-Douglas production function. is an adequate representation of the production function

Here H0= Quadratic production function: (β6 ……… β10=0)

H1 is implies that Quadratic production function is adequate representation of production function. Here β6 to β10 represent the quadratic terms.

(3) There is no inefficiency effect that is : H0=γ=0)

(4). The coefficients of determinants of inefficiency model equals zero that is H0=δ0=δ2……=δ12 =0

Table 1. Functional forms of the production functions for ML estimate

		Translog		Cobb-Douglas		Quadratic	
Variable	Parameter	Coeff.	SE	Coeff.	SE	Coeff.	SE
Intercept	β0	0.86	0.93	2.473***	0.286	3.167***	0.683
Lnoxen	β1	2.86***	0.91	0.024	0.071	0.065	0.128
Lnlabor	β2	1.03***	0.41	0.089**	0.048	0.093	0.203
Lnseed	β3	-0.53*	0.35	0.023	0.035	-0.315	0.275
Lnfert	β4	-0.06**	0.05	0.059***	0.003	0.057***	0.006
Lnarea	β5	1.38**	0.67	0.770***	0.068	0.812***	0.180
Lnox2	β6	-0.14**	0.08			-0.009	0.033
Lnlbor2	β7	-0.12**	0.05			0.000	0.030
Lnseed2	β8	0.04	0.04			0.037	0.030
Lnfert2	β9	0.02*	0.01			0.001	0.006
Lnarea2	β10	0.21	0.14			0.016	0.062
Lnox*lnlbor	β11	-0.49**	0.22				
Lnox*lnseed	β12	-0.07	0.13				
Lnoxen*lnfert	β13	0.05***	0.02				
Lnoxen*LnArea	β14	0.51**	0.27				
Lnlabor*lnseed	β15	0.04	0.05				
Lnlabor*Lnfert	β16	0.00	0.01				
Lnlabor*lnArea	β17	-0.02	0.13				
Lnseed*Lnfert	β18	0.01**	0.01				
Lnseed*Lnarea	β19	-0.10	0.09				
Lnfert*Lnarea	β20	-0.01	0.02				
Sigma-squared		0.18***	0.03	0.280	0.064	0.279***	0.067
Gamma		0.66***	0.07	0.733	0.096	0.740***	0.093
Mean efficiency		0.87		0.86		0.86	
LL function		-29.29		-40.528		-39.191	

*, **, *** implies significant at 10%,5% and 1% probability level respectively

Source: own computation, 2011

3.2 Results of the hypotheses test

The formulation and results of different hypotheses (model selection, inefficiency effect, determinants of coefficients) are presented in Table 1. All the hypotheses were tested by using generalized likelihood-ratio (LR). The first hypothesis related to the appropriateness of the Cobb-Douglas functional form in preference to translog model. The computed LR statistic was less than the table value at 5% significance level. The null hypothesis was accepted by indicating that the Cobb-Douglas functional form is a better representation of the data. These showed that the coefficients of the interaction terms and the square specifications of the input variables under the Translog specifications were not different from zero.

Table 2. Summary of hypotheses for parameters of stochastic frontier and inefficiency effects

Hypothesis	df	LH0	LH1	Calculated X2 (LR)	Critical X2	Decision
1. Production Function is Cobb-Douglas H0 : C-D (β6….β20=0); H1 : Translog production function	15	-40.54	-29.29	22.5	25	Accepted
2. Production Function is Cobb-Douglas H0 : C-D (β6….β10=0); H1 : Quadratic production function	5	-40.54	-39.19	2.6	11	Accepted
3. H0: μ=0 distribution assumption	1	53.75	54.85	2.2	2.71	Accepted
4. There is no inefficiency component (H0: γ=0)	1	-57.97	-40.53	34.8	3.84	Rejected
5. The coefficients of determinants of inefficiency model equals zero H0=δ0=δ2……=δ12 =0	12	-53.75	-40.3	26.9	25	Rejected

Source: Own Computation, 2011

The second hypothesis related to the appropriateness of the Cobb-Douglas in preference to the quadratic functional form. This hypothesis was also accepted at 5% level of significance and indicated that Cobb-Douglas functional form was again a better formulation than the Quadratic functional form. Hence the coefficients of the square specifications of the input variables under the Quadratic specifications were not different from zero. After testing both Translog and Quadratic function to determine whether there was adequate representation of the data, and found conclusive evidence that they were not. Hence, CD production function was the best to fit the data for estimation of technical efficiency for maize producing farm household in the study area.

The third 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 μi. The results indicated that the half normal distribution was appropriate for the sample households in the study area as the calculated LR value of 2.2 was less than the critical X2 value of 2.71 at 5% significance level.

The fourth hypothesis was tested for the existence of the inefficiency component of the total error term of the stochastic production function. In other words, it was concluded whether the average production function (without considering the non-negative random error term) best fits the data. Hence, the fourth hypothesis stated that γ=0, was rejected at the 5% level of significance confirming that inefficiencies existed and were indeed stochastic (LR statistic 34.8> λ21,0.95 =2.71). The coefficient for the parameter γ could be interpreted in such a way that about 73 percent of the variability in maize output in the study area was attributable to technical inefficiency effect, while the remaining about 27 percent variation in output was due to the effect of random noise. This implies that there was a scope for improving output of maize by first identifying those institutional, socioeconomic and farm specific factors causing this variation.

The fifth hypothesis which stated the technical inefficiency effects were not related to the variables specified in the inefficiency effect model, was also rejected at the 5% level of significance (LR statistic 26.9 > λ212,0.95 =25). Thus the observed inefficiency among the maize farmers in Dhidhessa could be attributed to the variables specified in the model and the variables exercised a significant role in explaining the observed inefficiency.

3.3 Parameter estimates of the SPF model

Table 3 presents the results of both the OLS and ML estimates. In total nineteen parameters were estimated in the stochastic production frontier model including five in the C-D production frontier model, and twelve explanatory variables were hypothesized to influence the technical efficiency scores while the remaining two being the parameters associated with the distribution of μi and vi. Out of the nineteen parameters estimated, twelve were statistically significant. From twelve significant parameters, five were significant at one percent level; the same numbers of variables were significant at five percent level while the remaining two were significant at 10 percent level of significance.

During the estimation, a single estimation procedure was applied using the CD functional form. The computer program FRONTIER version 4.1 gave the value of the parameter estimations for the frontier model and the value of 2. Moreover it gave the value of Log-likelihood function for both OLS estimations and the stochastic production function. The Maximum Likelihood estimates of the parameter of SPF functions together with the inefficiency effects model are presented in table 3 below.

Table 3. Cobb-Douglas stochastic production frontier Maximum likelihood and OLS estimate

Variable	Parameter	OLS		MLE	
		Coefficient	t-ratio	Coefficient	t-ratio
Intercept	β0	2.053	6.92***	2.473	8.65***
LnOx	β1	-0.001	-0.02	0.024	0.33
Lnlabor	β2	0.114	2.27**	0.089	1.86**
lnseed	β3	0.050	1.41	0.023	0.67
Lnchemfert	β4	0.059	13.63***	0.059	17.86***
LnArea	β5	0.712	9.56***	0.77	11.35***
Inefficiency effect model					
Sigma-squared	σ2	-	-	0.28	4.39***
Gamma	γ	-	-	0.73	7.65***
LL		-57.97	-	-40.52	-
Total sample size (N)		168	-	168	-

***, ** implies significant at 1% and 5% probability level, respectively

Source: Own Computation, 2011

3.4 Variability in output due to difference in the technical efficiency

The Maximum Likelihood estimation of the frontier model gave the value for the parameter (γ), which is the ratio of the variance of the inefficiency component to the total error term ($\gamma = \sigma u2/(\sigma v2 + \sigma 2u) = \sigma u2/\sigma s2$. The γ value indicated the relative variability of the one sided error term to the total error-term. In other words, it measured the extent of variability between observed and frontier output that is affected by the technical inefficiency.

As a result the total variation in output from the maximum may not necessarily caused efficiency differentials among the sample households. Hence, the disturbance term had also contributed in varying the output level. In this case, it was crucial in determining the relative contribution of both usual random noises and the inefficiency component in total variability. The TE analysis revealed that technical efficiency score of sample farms varied from 24% to 96%, with the mean efficiency level being 86%. This variation was also confirmed by the value of gamma (γ) that was 0.73. The gamma value of 0.73 suggested that 73% variation in output was due to the differences in technical efficiencies of farm household in Dhidhessa while the remaining 27% was due to the effect of the disturbance term. Moreover, the corresponding variance-ratio parameter implied that 14 % differences between observed and maximum frontier output for maize was due to the existing differences in efficiency among the sample farms. These provided opportunity for improving maize output by investigating factors that influence efficiency in order to improve the productivity of maize in the study area.

3.5 Estimated actual and potential level of output

Applying equation 8 below the potential attainable level of maize yield per ha was obtained. The difference between the actual level and the frontier level of output was computed by estimating the individual and the mean level of frontier output. From the stochastic model in equation (12), the actual output was given by: Yi: exp (Xi β+ Vi-Ui). From this equation, technical efficiency (exp-ui) is given as

TEi= Yi/Yi* ……………………………………………………………8

Where TEi = technical efficiency of the ith household in maize production

Yi* = the frontier output of the ith household in maize production,

Yi = the actual output of the ith household in maize production.

Then Yi* = Yi/TEi = exp (Xi β + Vi-Ui)/exp (-Ui) = exp (Xi β + Vi)………..9

Using the values of the actual output obtained and the predicted technical efficiency indices, the potential output was estimated for each sample farm households. The mean levels of the actual and potential output during the production year were 23.4 Qt/ha and 26.8 Qt/ha, with the standard error of 11.8 and 12.4, respectively. Moreover, paired sample t-test was used on the actual and potential yield to compare the difference in the amount of yield between two scenarios. There was a significant difference between potential yield and actual yield. The mean difference of the actual and the potential output was found to be statistically significant at 1% probability level. Figure 3 illustrates that under the existing practices there was a scope to increase maize yield following the best-practiced farms in the area.

Table 4. Comparison of estimated actual yield and potential yield of sample respondent

	Potential yield per hectare		Actual yield per hectare	
Efficiency category	Mean	Std. Deviation	Mean	Std. Deviation
0.20-0.70	18.07	10.68	7.46	7.50
0.71-0.81	26.70	9.37	20.76	7.51
0.82-0.86	21.62	8.06	18.33	6.80
0.87-0.90	25.93	10.50	22.94	9.30
Above 0. 90	30.21	14.50	28.05	13.52
Average efficient	27.39	12.59	24.46	11.70
Less efficiency	21.28	9.22	14.07	7.82
Overall	26.81	12.41	23.47	11.77

Source: own survey, 2011

Potential yield was also calculated for each farm and the results were presented by range of technical efficiency group. In general, for the less efficient farm households the recorded average actual yield was 14 qt/ha. Their corresponding averagely efficient group potential yield was 21qt/ha. The highest difference between actual and potential yield was analyzed for 20% of the sample household. The potential yield for this group was found to more than 50% of their actual yield. On the other hand, the net magnitude of yield improvement through efficient utilization of existing resource for less and averagely efficient farmers were approximately 7.2 and 2.5qt/ha. At district level, working towards improving the efficiency of the farmers could bring additional yield of 2060 qt of maize given 7550 ha of total land area allocated for maize production in the study period. These findings may invite attention of the policy makers and district experts to improve the efficiency of the farmers through adoption of right strategy to efficiently utilize the existing resource to improve the food security of the district.

3.6 Determinants of Technical efficiency

The focus of this analysis was to provide an empirical evidence of the determinants of productivity variability/inefficiency gaps among smallholder maize farmers in the study area. Merely having knowledge that farmers were technically inefficient might not be useful unless the sources of the inefficiency are identified. Thus, in the second stage of this analysis, the study investigated farm and farmer-specific attributes that had impact on smallholders' technical efficiency.

The parameters of the explanatory variables in the inefficiency model were simultaneously estimated in a single stage estimation procedure using computer program, FRONTIER 4.1. The dependent variable of the model was inefficiency and the negative signs implied that an increase in the explanatory variable would decrease the corresponding level of inefficiency.

Table 5 showed the coefficients of explanatory variables in the inefficiency model. The results showed that most of the signs related to inefficiency determinants were as expected. The model results showed that factors such as age, education, labor availability improved seed, training, were negatively related with inefficiency while off farm activity, interaction between education and off-farm income, number of livestock and distance to market were positively related with inefficiency. Although distance to maize plot and land fragmentation have expected sign but did not turn out to be significant.

Education enhances the acquisition and utilization of information on improved technology by the farmers. The results showed that farmers with more years of formal schooling were more efficient than their counterparts (Table 5). This result was consistent with the findings of Abdulai and Eberlin (2001) which established that an increase in human capital will augment the productivity of farmers. Similar results had been reported in studies which had focused on the association between formal education and technical efficiency (Nyagaka et al. (2009); Fekadu, 2004 and Kinde, 2005). On the other hand the age of the household influenced inefficiency negatively. This suggested that older farmers were more efficient than their young counterparts. The reason for this was probably because the farmers become more skill full as they grow older due to cumulative farming experiences (Liu and Zhung, 2000). Similar conclusions were made by Omonona (2010) and Awudu and Huffman (2000). Moreover the coefficient of the dummy representing the use of improved seeds was statistically significant at 10 percent level. Thus, production of maize through the use of improved maize seeds resulted in more technical efficiency as compared to using local seeds. It means that the tendency for any maize farmers to increase his production depend on the type and quality of improved seed available at the right time of sowing. This was in agreement with the findings of Ephraim (2007).

Table 5. Maximum-likelihood Estimates of technical efficiency determinants

Variables	Coefficients	SE	t-ratio
Constant	1.47	1.29	1.14
Age	-0.22*	0.13	-1.76
Education	-0.21**	0.11	-2.00
Improved seed	-1.17**	0.59	-1.98
Off farm Activity	1.71**	0.97	1.76
Training	-0.54***	0.23	-2.34
Fragmentation	0.16	0.13	1.27
Labor availability	-0.43*	0.27	-1.58
Distance to maize	0.10	0.09	1.09
TLU	0.06*	0.04	1.67
Education and off-farm income	0.30***	0.12	2.42
Distance to market	0.08*	0.05	1.51
Off farm and Labor availability	-0.157	0.218	-0.72
Sigma square	0.280***	0.064	4.388
Gamma	0.733***	0.096	7.654
LL	-40.52		
Mean Efficiency	0.86		
Returns to scale	0.956		

*, **, *** implies significant at 10%, 5% and 1% probability level respectively
Source: own computation, 2011

A number of farmers in the study areas received training on maize for few days mainly on production practices and importance of using improved package. The dummy coefficient of training was negative and significant in the technical inefficiency model for maize production (table 5). This result was in line with the arguments by Fekadu (2004) who indicated that training given outside locality relatively for longer period of time determined efficiency positively and significantly. Hasan and Islam (2010) and Abebe (2009) also found training to be positively related to technical efficiency. Moreover off farm income was positive and significant with technical inefficiency. This implied that, farmers who participated in off-farm activity were likely to be less efficient in farming as they share their time between farming and other income-generating activities. Productivity suffers when any part of production is neglected. Especially in the study area, due to employment opportunities available due export commodities such as coffee, the majority of the farmers neglect weeding of their maize crop. This finding was in agreement with that of Mariano et al. (2010) and Goodness et al.(2010). Similarly, the interaction between off-farm income and education variable were found to be positive and significant indicating the farmers who were educated and engaged in generating off-farm income tended to exhibit lower technical efficiency levels in maize production. This might suggested that farm household academic curiosity in the existence of more profitable coffee enterprise production might dictate them to reallocate most of their time away from maize crop management related activities. As a result the farmers use less time to exercise maize appropriate maize management practices which was essential for enhancing technical efficiency (Huffman and Zhung, 2000).

In addition the coefficient of labor availability was found to be negative and significant in the technical inefficiency model. This implies that technical inefficiency decreases with the increase in labor availability. Hence the farmers who had more available labor were better managers; therefore, they produced closer to their production frontier which is similar with Hassen (2011). Moreover it was hypothesized that number of livestock influenced technical efficiency positively. Nevertheless the coefficient is found to be significant and negative with technical efficiency. This might be attributed to the tendency of the farmers who held large number of livestock reallocated much of their time in herding livestock and hence less time for crop management. Due to this fact, farmers who owned large livestock might be less technical efficient as compared to those who possessed large livestock. The finding was consistent with the findings of Fekadu (2004). Finally, proximity to market affected the technical efficiency in different ways. The hypothesis in this study was that households located near markets were expected to have higher technical efficiency than those located in remote areas. It was assumed that that proximity to markets increased the opportunities of farmers to sell their products and purchase input at nearest distance. In contrast, some research argued that access to markets might increase the non-farm employment opportunities with higher returns than from farming, leading farmers to reallocate labor from farm to non-farm activities. In this analysis, it was observed that proximity to markets reduces technical inefficiency levels significantly. The result was consistent with the finding of Alemu et al (2007).

4. SUMMARY, CONCLUSIONS and RECOMMENDATIONS

4.1 Summary and Conclusions

The primary objective of this study was to analyze determinants of technical efficiency in smallholder maize production system in Dhidhessa district. This was achieved by measuring the efficiency of smallholder maize farmers and identifying the determinants of technical efficiency. The results obtained from the stochastic frontier estimation showed that inefficiency was present in maize production among smallholders. Sufficient evidence of positive relationship between maize productivity and higher use of intermediate inputs such as fertilizer and land utilization were practiced. The results of efficiency analysis showed that smallholder farmers could improve their efficiency by operating closer to production frontier. Thus, there existed considerable scope to expand output and also productivity by decreasing the average yield gap which was estimated to be around 334 kg/ha if inputs were efficiently utilized. Moreover, for 20% of less efficient sample respondent working towards the improvement of efficiency could increase the yield by more than 50%. At district level, working towards improving the efficiency of the farmers could bring additional gross output of 2060 qt of maize given 7550 ha of total land area allocated for maize production during the study period.

The above mentioned amount of output and efficiency of maize production could be obtained significantly by paying more attention to the determinants of technical efficiency. Some of the areas which demand more attention where timely providing improved maize seed and encouraging farmers to use recommended management practices. In addition technical inefficiency decreased (i.e. efficiency increased) with the increased in education and training on maize production packages. Thus, it was needed in a priority basis to invest in public education to explore and develop human resources for the farm operation and intensifying training in maize extension packages. Moreover, the average technical efficiency of maize production in Dhidhessa district was 86 percent indicating a good potential for increasing maize output by 14 percent with the existing technology and levels of inputs.

In general, the existence of inefficiency level in maize production and identification of inefficiency variables had important policy implications in improving the productivity in the study area. Thus, integrated development efforts that will improve the existing level of input use and policy measures towards decreasing the existing level of inefficiency will have paramount importance in improving the food security in the study area.

4.2 Recommendations

1. Based on the above results, the followings recommendations are made:
2. Designing policy which encourages the experience sharing among farmers with regard to utilization of intermediate input would help to improve maize productivity. Nevertheless the attention of policy makers to mitigate the existing level of low maize productivity and poverty should not stick only to the introduction and dissemination of inputs (esp. fertilizer). Side by side equitable attention has to be given towards improving the existing level of efficiency at least by sharing best practices among farmers through field days and on farm demonstration.
3. More efforts should be intensified on by Agricultural offices in training and encouraging farmers to use improved agronomic practices throughout the study area.
4. There should be timely supply of fertilizer and quality improved seed to improve farmers' efficiency in production of maize.
5. Strengthening the existing extension services delivered to farmers specific efforts should be made to train and monitor farm household with regard to improved maize management practices.

5. REFERENCEs

Abebe Dagnew, 2009. Technical Efficiency of Onion Production Under Irrigation: The Case of Kalu District of South Wollo, Ethiopia M.Sc. Thesis Presented to School of Graduate Studies of Alemaya University.

Aigner, k., P. Schmid and D. Lovell, 1977. Formulation and estimation of stochastic production function models. Journal of Econometrics. 5: 21-37.

Alemu Bamlaku, H. Bolan and E. Nuppenaud, 2007. Technical Efficiency of Farming Systems across Agro-ecological Zones in Ethiopia: An Application of Stochastic Frontier Analysis.

Aynalem Gezahegn, 2006. Technical Efficiency in Maize Production: A Case of Smallholder Farmers in Mecha District, Ethiopia. An M.Sc. Thesis Presented to School of Graduate studies of Alemaya University.

Coelli T., D. S. P. Rao and G. E. Battese,1998. An Introduction to Efficiency and Productivity Analysis, Kluwer Academic Publishers, Norwel, Massachusetts, U.S.A.

Coelli, T. (1996a). A guide to FRONTIER version 4.1: a computer program for frontier production function estimation. CEPA Working Paper 96/07, Department of Econometrics, University of New England, Armidale, Australia.

CSA (Central Statistical Agency),2009. Agricultural Sample Survey Volume I Report on Area and Production of Crops (Private Peasant Holdings,) Addis Ababa, Ethiopia.

Nyagaka, D.O , Daniel O., G.A. Obare and W. Nguyo, 2009. Economic Efficiency of Smallholder Irish Potato

Producers in Kenya: A Case of Nyandarua North District. Department of Agricultural Economics and Agribusiness Management, Egerton University, Kenya.
Ephraim, A., W. Chirwa, 2007. Sources of Technical Efficiency among Smallholder Maize Farmers in Southern Malawi. African Economic Research Consortium.Nairobi,Kenya.
Fekadu Gelaw, 2004. Analysis of Technical Efficiency of Wheat Production: A Study in Machakel Woreda, Ethiopia. M.Sc. Thesis Presented to School of Graduate Studies of Alemaya University.
Hasan, M.K and S. M. Islam, 2010.Technical Inefficiency of Wheat Production in some Selected Areas of Bangladesh. Bangladesh J. Agril. Res. 35(1) : 101-112.
Hassen Beshir, 2011. Analysis of agricultural technology adoption and Production efficiency: the case of smallholder farmers in North eastern highlands of Ethiopia. A PhD dissertation submitted to the college of agriculture and environmental sciences, School of agricultural economics and agribusiness, school of graduate studies, Haramaya university
Mariano M.J, R. Villano, E. Fleming, R. Acda, 2010. Meta frontier analysis of farm-level efficiencies and environmental-technology gaps in Philippine rice farming.Australia
Noah, E., 2005. Grain Production in Kenya, Export Processing Zones Authority.Nairobi Kenya.
Omonona, B.T., O.A. Egbetokun and A.T. Akanbi (2010). Farmers Resource Use and Technical Efficiency in Cowpea Production in Nigeria. Department of Agricultural Economics, University of Ibadan, Ibadan, Oyo State, Nigeria. Economic Analysis & Policy, Vol. 40 No. 1.
Salvatore, D and D. Reagle, 2002. Theory and problems of statistics and econometrics, Second edition Schaum's Outline Series The McGraw-Hill Companies, Inc. New York.
Sankhayan, P.L., 1988. Introduction to the Economic of Agricultural Production. Prentice Hall of India Pvt. Limited. India.
Tefera Bayissa, Hayilu Sendaba and Remadan Abdela, 2011. Dhidhessa District Agriculture and Rural development office , Development Plan and Program of Dhidhessa District.
Xinshen, D., 2010. Policies for Agricultural Development, Poverty Reduction and Food Security:The Case Study of Ethiopia. IFPRI.

Appendix 1

Sampling Method Specification

Very large sample size has very small error in making decision about the population. Hence the following

method was used to determine the size of the sample. Consider a population whose mean (μ) is unknown and variance (σ^2) is known. If a sample size n is selected from the population, the confidence interval is estimated using the sample mean ($\bar{X}$) at a desired significance level (α) (Salvatore and Reagle, 2002).Then

$$\bar{X} \sim N\left(\mu, \frac{\sigma^2}{\sqrt{n}}\right) \text{..1}$$

The confidence interval was computed as follows:

$$\mu = \bar{X} \pm Z_{\alpha/2}\left(\alpha/\sqrt{n}\right)$$

If the desired accuracy about the mean is D, then the confidence interval was obtained as confidence interval of $\mu = \bar{X} \pm D$

Therefore, $Z_{\alpha/2}\left(\alpha/\sqrt{n}\right) = D$

The appropriate sample size (n) was determined by the formula (Panneerselvam, 2011; Hassen Beshir, 2011).

$$n = \left\{ (Z_{\alpha/2}\,\sigma)/D \right\}^2 \text{..2}$$

Where Z is considered to be the standard normal distribution

For the study area, the standard deviation for crop output per ha from previous studies was 98 kg (Tefera et al., 2011). Suppose the desired accuracy about the mean of crop output per hectare was within ±15 kg with a confidence interval of 95%. Therefore, based on the formula, in the second stage, the appropriate sample size for the study was 162 sample farmers or 9.4% of the total farmers were selected randomly.

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