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Technical Efficiency Difference between Model and Non-Model Smallholder Wheat Producer Farmers in Lode Hetosa Woreda of East Arsi Zone of Oromia Regional State, Ethiopia, by Meshesha Zewdie[1], Dessalegn Shamebo [2]

Abstract

The smallholder farming system in Ethiopia is largely dominated by staple food crops which are exposed to managerial inefficiency and factors beyond the control of the farmer. Accordingly, the study aimed to analyze technical efficiency differences between model and non-model smallholder wheat producer farmers and inefficiency determinants in Hetosa Woreda of East Arsi Zone. The Stochastic Production Frontier Cobb-Douglas functional form was used. To analyze cross-sectional data collected from 700(350 model and 350 non-model) farmers for the production year of 2018/19, descriptive and econometric data analysis techniques were used. The findings of the descriptive analysis showed that model farmers produced an average of 32.82 and non-model farmers produced on average 29.36 quintals of wheat per hectare. The value of the discrepancy ratio (γ) which indicates technical inefficiency variability was 89%, 82%, and 84% for the model, non-model, and overall farmers respectively. The mean technical efficiency score was 81%, 79%, and 80% for the model, non-model, and overall farmers respectively. Land, fertilizer, and labor statistically significantly affected the wheat output of model farmers, whereas all input variables statistically significantly affected the wheat output of non-model farmers. In addition, model farmers' technical inefficiency was statistically significantly determined by the mode of plowing, mode of harvesting, shock, training, and marketing, and that of non-model farmers' technical inefficiency was statistically significantly affected by mode of harvesting, level of education, land fragmentation, and marketing. Thus, training, market, education, and strategic plan to mitigate factors beyond the control of farmers need to be considered for improvement to make farmers more productive and technically efficient in wheat production in the study area.

Keywords: Technical efficiency, stochastic production frontier, model, and non-model farmers

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Introduction

Ethiopian Economy which highly depends on agriculture is characterized by small-scale, subsistence-oriented, traditional, and vulnerable to climate shocks. However, the agricultural sector accounts for more than 37% of the GDP, 70% of the annual export earnings, and 73% of rural employment (FAO, 2019). Ethiopian strategy to achieve overall economic growth largely depends on the performance of the agricultural sector. To sustain economic growth, reduce poverty and ensure food security, the sector needs substantial transformation. To this end, the government of Ethiopia made a series of economic reforms from 1991 onwards. Some of these reforms include the Structural Adjustment Programme (1991), Agricultural Development Led Industrialization (ADLI) Strategy (1993), the Interim Poverty Reduction Strategy Paper (IPRSP) (2000), Sustainable Development and Poverty Reduction Program (SDPRP) (2002), Plan for Accelerated and Sustained Development to End Poverty (PASDEP) (2005), and Growth and Transformation Plan (GTP) (2011) intending to bring fast economic growth through increased agricultural productivity.

To increase the production and productivity of wheat-producing smallholder farmers in Ethiopia, better use of modern agricultural technology and inputs are important which in turn can enhance the production efficiency of farmers (Shumet, 2012; Endrias et al., 2010). Ologbon and Yusuf (2012) further affirm that variances in productivity and efficiency among Nigerian producers of cereal crops can be attributed to the farmers' weed-controlling techniques. But the provision of improved agricultural technology is a supply-side issue for smallholder farmers, so that, understanding end users' capacity and demand to adopt the technology will have an immense contribution to the problem of productivity and technical efficiency of farmers.

Agricultural productivity can be increased either through introducing modern agricultural technologies or technical efficiency improvements. However, the introduction of new technologies alone regardless of knowing how efficient farmers are in using the existing technologies may result in a worsening of efficiency. Theoretically, the introduction of new technology can increase agricultural output. But Tarkamani and Hardarkar (1996) argued that in areas where there is inefficiency, trying to increase a new technology may not have the expected effect if the existing technology is not efficient. Thus, it needs integration of modern technology with an improved level of efficiency. But for developing countries like Ethiopia, increasing productivity through technical efficiency improvement is better than introducing modern technologies because introducing new technology demands more capital investment.

To this end, many researchers have proposed improvement in technical efficiency as a solution for optimal operation of cereal crop farming through the provision of better information, credit provision, extension visit, dissemination of improved technologies such as fertilizer, and improved high-yielding varieties and education (Shumet, 2012; Essa,211; Mussa et al., 2011; Alemayehu,2010; Jema, 2008). If farmers’ technical efficiency is low, the use of modern technology alone could not bring the expected shift of the production frontier. But smallholder farmers can still produce efficiently with a given fixed set of inputs and a given level of technology. Assefa et al. (2019) and Dessale (2019) found technical efficiency scores for smallholder wheat producer farmers 72% and 82% respectively.

Wheat is the staple crop food in Ethiopia in both urban and rural areas. Farmers of the Lode Hetosa Woreda cultivate wheat most commonly and tried their best to increase its production through the support obtained from development agents and agricultural experts by grouping farmers into the model and non-model. Here model farmers are farmers that are role models for neighboring farmers chosen by local governmental institutions and are successful farmers who are used as the principal agent to accept and disseminate technologies and information to follower farmers (non-model), otherwise, they are called non- model farmers (Stone, 2016). Model farmers are acting as nexus points in the flow of information, subsidies, and material inputs between extension agents and the local community (Taylor, 2018). Based on these definitions, Lode Hetosa Woreda agricultural office has grouped farmers into the model (4706 farmers) and non-model farmers (15601 farmers) (WAOR, 2019). Grouping of farmers was done yearly because there are farmers who are model a year before and maybe non-model this year and the same fact holds for non-model farmers.

This study will fill the gap that many researchers did not group farmers into the model and non-model to analyze the technical efficiency level of farmers (Assefa, 2019; Dessale, 2019; Getachew et al., 2020). This study compares the technical efficiency differences by grouping farmers into a model and non-model. Moreover, to the best knowledge of the researcher, there is no prior study carried out in the study area related to measuring the technical efficiency of wheat.

Therefore, the researchers are motivated to conduct this research to estimate the level of technical efficiency and identify factors contributing to inefficiency among model and non-model wheat-producing farmers in the study area and ultimately contribute recent data and information to the knowledge in the field.

Methods and Data

Description of the Study Area

Lode Hetosa is one of the *Woreda* in the East Arsi Zone of the Oromia National Regional State. It is 164 kilometers southeast of Addis Ababa and has 19 kebele or peasant organizations. The *Woreda* is home to 151,718 people in total. According to the Woreda profile from 2019, the Woreda is distinguished by a bimodal rainfall pattern with an average annual rainfall of 800-1200 mm, temperature ranges from 10°C to 27°C, and 60%, 35%, and 5% of the Woreda's agro-climate conditions are mid highland, highland, and lowland, respectively. Another characteristic of the Woreda is the mixed farming system (crops and cattle). Additionally, it has a total area under cultivation of 25,940 hectares, with crop production as the leading industry. Farmers' primary agricultural activity is the production of wheat. Cereals (wheat, barley, teff), pulses (fava bean, pea, haricot bean, and lentil), oil seed (linseed), and vegetables (onion, tomato, potato, head cabbage, and carrot) are the main annual crops farmed (*Woreda* profile, 2019).

Study Design

The study used an explanatory research design because the main aim of the study is to estimate technical efficiency and identify inefficiency differential among model and non-model smallholder wheat-producing farmers. And quantitative cross-sectional primary data for the production period of 2018/19 was collected from samples drawn from the population.

Sample Size and Selection Technique

Lode Hetosa Woreda was purposively picked out of all the *Woreda* in the East Arsi Zone of the Oromia National Regional State. This *Woreda* is more suited for growing wheat and has used more than 90% of its arable land compared to other *Woreda*. Twelve of the 19 *kebeles* found in the Woreda have the greatest potential for producing wheat. Then, using multistage and simple random sampling techniques, eight out of 12 prospective wheat-producing *kebeles* were picked. At these eight kebele farmer training centers (FTC), lists of 1980 model and 6568 non-model farmers are provided with various numbers in each *kebele* (*Woreda* Profile 2019). To achieve a sample size of 700, 350 model and 350 non-model farmers were chosen at random from lists of farmers located in each kebele, with the chance for each selection being proportionate to the size of the *kebele* under study. An equal sample size was used to compare the efficiency mean scores of model and non-model farmers. The primary data was gathered using a structured questionnaire and the scheduling technique.

Method of Data Analysis

Descriptive and econometric data analysis methods were used. Descriptive analysis was applied to describe variables used in the models. The econometric method was used to analyze the effect of the independent variables on the dependent variables.

Measurement of Efficiency

Efficiency measures have their roots in the writings of Debreu (1951), Koopmans (1951), Farrell (1957), Charnes and Cooper (1957), and Shephard (1970). The estimation of efficiency is based on the estimation of a frontier, which indicates the greatest output from a set of inputs and fixed technology. However, since this frontier function is unknown in practice, it will be approximated using a sample of actual production units, and each firm's performance will be compared to the predicted frontier to determine its efficiency. Input-oriented and output-oriented techniques are the two approaches (Coelli et al., 1998). Does the input-oriented efficiency concept discuss how much can a production unit proportionally reduce the quantities of inputs used to produce a given amount of output? The output-oriented states by how much can output be increased without increasing the number of inputs used (Coelli et al., 1998)

Methods of Estimating Efficiency

Frontier models can be broadly divided into two types. These are parametric and non-parametric frontier models. The parametric frontier model can also be divided into stochastic and deterministic frontier models. The non-parametric efficiency model, also known as data envelopment analysis (DEA), uses the linear programming method to create a non-parametric 'piece-wise' surface (or frontier) over the data. The parametric models are essentially estimated using econometric methods. According to Battese et al. (2005), the parametric approach entails specifying a functional form for the production technology and assuming the distribution of the error terms. In this work, models developed independently by Meeusen and van den Broeck (1977) and the parametric stochastic frontier (composed error) model by Aigner et al. (1977) were used.

Selection of Functional Form

Stochastic production frontier analysis frequently uses the Cobb-Douglas and trans-log functional forms. The stochastic production frontier is, nevertheless, commonly estimated using the Cobb-Douglas functional form. It is widely used in agricultural economics studies because it can estimate technical efficiency while considering farm-specific technical inefficiency factors and random factors that have no control over the observed technical efficiency level (Coelli et al., 1998).

Estimation of the Input Model

Equation 2.1 illustrates the stochastic frontier function introduced by Aigner et al. (1977) and Meeusen and van den Broeck (1977). Aigner, Lovell, and Schmidt (1977) obtained maximum likelihood (ML) estimates under the assumption of v_i- iid N (0, v^2) and u_i-iid N+ (0, u^2), however, because the model requires half-normal distribution, the model was stated as follows:

$\ln(y_i) = X_i\beta + v_i - u_i$, i = 1, 2,... N (2.1)

Where: ln: represents the natural logarithm to the base" e"

y_i: total wheat output in quintals for the ith farmer.

X_i: is a vector of input variables for the ith farmer

β: parameters to be estimated.

v_i: is the disturbance error term, independently and identically distributed(iid) as N $(0,\sigma v^2)$ intended to capture events beyond the control of farmers with mean value zero and constant variance(σv^2)

u_i: is a non-negative half-normal random variable, independently and identically distributed(iid) as N+(0, $\sigma^2 u$) with mean value zero and constant variance(σv^2) intended to capture technical inefficiency effects in wheat output.

That is to say; the output-oriented technical efficiency of the ith farmer, denoted by TE_i, can be estimated as the ratio of the observed output (y_i) and maximum potential output (y*):

$TEi= y_i / y^* = (f(x_{ij}; \beta) \text{ x } \exp(v_i-u_i))/(f(x_{ij}; \beta) \text{ x } \exp(v_i)) = \exp(-u_i)$ (2.2)

Where:

i, j: denote the farm and input respectively, TE_i: technical efficiency of the ith farmer, $\exp(-u_i)$: the expected value of $-u_i$.

Output and input variables used in this model are:

Wheat Yield (Woutp): This is a dependent variable used to measure the amount of wheat produced in quintals for the production period 2018/2019).

Land (land): Land cultivated for wheat production in the year 2018/19 was measured in hectares. Fertilizer **(Fert):** UREA or DAP or both fertilizers are used in quintals per hectare.

Improved Seed (Imp. seed): This is the amount of improved wheat seed used by farmers per hectare of wheat land cultivated.

Local seed (LSeed): This is the amount of local wheat seed used by farmers per hectare of wheat land cultivated.

Labor (labr): It can be hired, or family labor involved in wheat farming. The family and hired labor used were measured on the bases of person-day conversion, which is eight working hours considered as one person-day.

Chemical (chem): Chemicals are used by farmers to control weeds and pests. Therefore, farmers were asked how much ml of chemical they applied in the last cropping season for wheat farming.

The input model was written as:

$\ln(woutp) = \beta_o + \beta_1 \ln(land) + \beta_2 \ln(Fert) + \beta_3 \ln(Impseed) + \beta_4 \ln(labr) + \beta_5 (chem) + v_i - u_i$, $\varepsilon_i = v_i - u_i$ (2.3)

Predicting Farm-Specific Efficiency

The best prediction of farm-level efficiency, exp (-ui), can be obtained by

$E[\exp(-ui) / ei] = (1-\Box(\sigma\_A+[\![\gamma e]\!]\_i/\sigma\_A))/(1-\Box([\![\gamma e]\!]\_i/\sigma\_A)) \exp(\gamma ei + \sigma^2/2)$

$\sigma A = \sqrt{}(\gamma(1-\gamma)\ \sigma\_S^{\wedge 2}); ei = \ln(yi) - X_i\ \beta; \Box(.)$ (2.4)

Where; □(.) the density function of a standard normal random variable which can be estimated by maximum likelihood once the density function for ui is specified. The maximum likelihood estimates of the parameters of the frontier model are estimated, such that the variance parameters are expressed in terms of the parameterization.

$\sigma^2 s = \sigma^2 v + \sigma u^2$ and (2.5)

$\gamma = \sigma u^2/ \sigma^2 s = \sigma u^2/ \sigma v^2 + \sigma u^2$ (2.6)

Where: the γ parameter has a value between 0 and 1. A value of γ of zero indicates that the deviations from the frontier are due entirely to noise, while a value of one would indicate that all deviations are due to technical inefficiency.

σu^2 - is the variance parameter that denotes deviation from the frontier due to inefficiency.

$\sigma^2 v$ - is the variance parameter that denotes deviation from the frontier due to noise.

$\sigma^2 s$ - is the variance parameter that denotes the total deviation from the frontier.

Estimation of Inefficiency Effect Model

All the parameters were estimated using a one-step technique. Because the inefficiencies are expected to be independently and identically distributed (iid) to estimate their values, both the production frontier and the inefficiency effect models are estimated simultaneously (Coelli et al., 1998; Herrero and Pascoe, 2002). Consequently, farm-specific inefficiency effects, u_i's, assuming, for example, a half-normal distribution N+ (0, σu^2) is modeled as follows:

$U_i = Z_i \delta + w_i$ i = 1,2,………N (2.7)

Where; U_i - is inefficiency effects

δ - is a 1xP vector of parameters to be estimated by the maximum likelihood estimator, which would generally be expected to include an intercept parameter

Z_i – is a Px1 vector of explanatory variables associated with farm-specific inefficiency effects.

w_i – is assumed to be a normally distributed random variable with mean zero and variance $\delta^2 w$ or $w_i \sim N(0, \delta^2 w)$

The following variables were used and estimated in the inefficiency effect model. These are:

Age (age): This refers to the age of the farmer measured in a number of years.

Age². This variable was used to see the diminishing effect of age on efficiency.

Sex (sex): It is a dummy variable that assumes "1" if a farmer is male-headed and "0" if otherwise.

Education Level (educ): This refers to the educational level of the farmers. It is measured in years of formal schooling of the farmers and then grouped into categorical variables.

Extension Contact (extcont): This variable was measured by the number of visits made per week by development agents concerning wheat production in the cropping year.

Training (training): This is a dummy variable that assumes "1" if a farmer gets training related to wheat production and "0" otherwise in the cropping year. A farmer can train more than one in a cropping period.

Shock (shock): This is a dummy variable that assumes 1 if farmers faced a shock within the production year and "0" otherwise. Shock includes crop disease, weeds, lack of rainfall, high-intensity rainfall, and frost.

Land fragmentation (land frag): This is the number of plots of land a farmer plows for wheat production. It includes both owned and rented plots.

Market (Markt): This variable was used to indicate whether a farmer faced any problem related to the marketing of his wheat product. If farmers do not have problems with the market, it is more likely that farmers will produce more in response to the benefit they obtained from the market and affecting inefficiency negatively.

Harvesting (Harvest): This is a categorical variable that indicated the mode of harvesting a farmer practice in wheat farming and assume one if a farmer uses only a combiner, two if a farmer harvest only manually, and 3 if a farmer used both a combiner, and manual.

Plowing (plow): This refers to the mode of plowing a farmer exercises in the cropping year. It is a categorical variable and assumes 1 if a farmer used oxen only, 2 if a farmer used a tractor only, and 3 if a farmer used oxen and a tractor.

Therefore, the inefficiency model is written as:

$U_i=\delta_0+\delta_1(age)+\delta_2(age^2)+\delta_3(sex)+\delta_4(educ)+\delta_5(training)+\delta_6(exts)+\delta_7(shock)+\delta_8(markt)+\delta_9(harvest)+\delta_{10}(plow)+\omega_i$ (2.8)

Finally, both the input and inefficiency models were estimated simultaneously and specified as:

$$\ln(woutp) = \beta o + \beta_1 \ln(land) + \beta_2 \ln(Fert) + \beta_3 \ln(Impseed) + \beta_4 \ln(labr) + \beta_5 (chem) (\delta_0+\delta_1(age)+\delta_2(age^2)+\delta_3(sex)+\delta_4(educ)+\delta_5(training)+\delta_6(exts)+\delta_7(shock)+\delta_8(markt)+\delta_9(harvest)+\delta_{10}(plow)+\omega_i \quad (2.9)$$

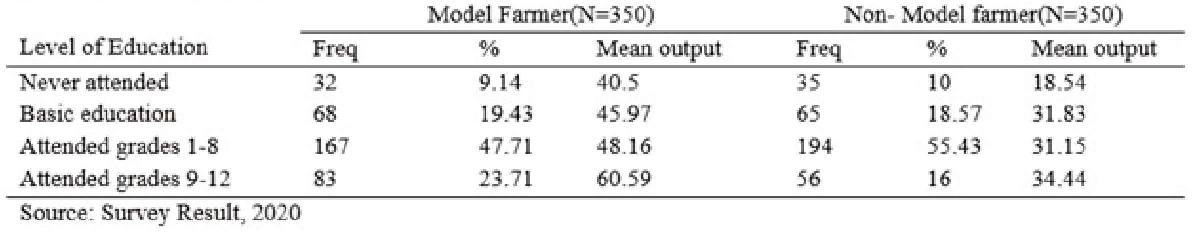
Results and Discussion

Descriptive Results

The mean age of the model and non-model farmers was 51.38 and 47.16 years respectively. The mean age difference between model and non-model farmers is statistically significant at a 1% level (t= 4.9291, p=0.000). Regarding family size, on average, model farmers have slightly higher family size (5.2) compared to non-model farmers (4.6) and the difference is statistically significant at a 1% level (t=4.6229, p= 0.000).

Education is one variable described in this study. The descriptive results of the education level of farmers were presented in Table 1.

Table 1: Average Wheat output by the level of education and Groups of farmers



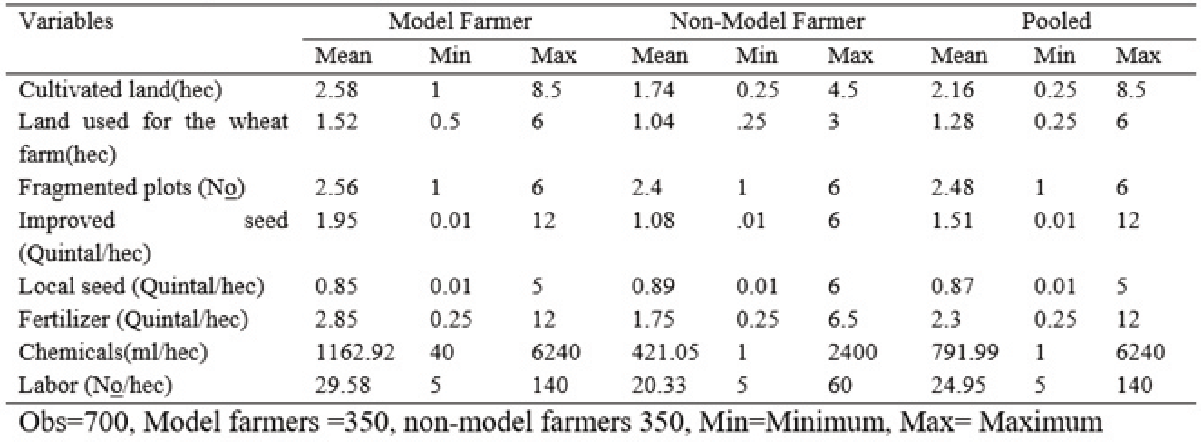
	Model Farmer(N=350)			Non- Model farmer(N=350)		
Level of Education	Freq	%	Mean output	Freq	%	Mean output
Never attended	32	9.14	40.5	35	10	18.54
Basic education	68	19.43	45.97	65	18.57	31.83
Attended grades 1-8	167	47.71	48.16	194	55.43	31.15
Attended grades 9-12	83	23.71	60.59	56	16	34.44

Source: Survey Result, 2020

Input Variables

Land, selected seed, local seed, chemical fertilizer, and labor are one of the most important variables that can affect the output of farmers. The descriptive results of these variables were presented in Table 2.

Table 2: Descriptive Results of the Input Variable



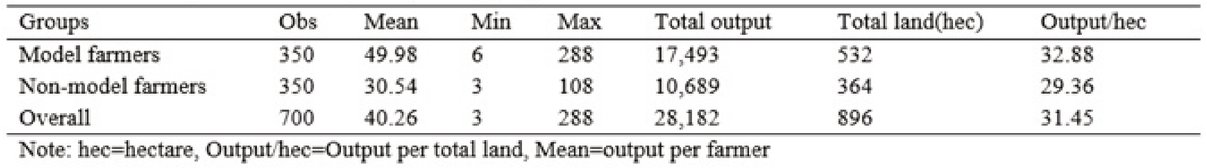
Variables	Model Farmer			Non-Model Farmer			Pooled		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Cultivated land(hec)	2.58	1	8.5	1.74	0.25	4.5	2.16	0.25	8.5
Land used for the wheat farm(hec)	1.52	0.5	6	1.04	.25	3	1.28	0.25	6
Fragmented plots (No)	2.56	1	6	2.4	1	6	2.48	1	6
Improved seed (Quintal/hec)	1.95	0.01	12	1.08	.01	6	1.51	0.01	12
Local seed (Quintal/hec)	0.85	0.01	5	0.89	0.01	6	0.87	0.01	5
Fertilizer (Quintal/hec)	2.85	0.25	12	1.75	0.25	6.5	2.3	0.25	12
Chemicals(ml/hec)	1162.92	40	6240	421.05	1	2400	791.99	1	6240
Labor (No/hec)	29.58	5	140	20.33	5	60	24.95	5	140

Obs=700, Model farmers =350, non-model farmers 350, Min=Minimum, Max= Maximum

Wheat Output

The descriptive result in Table 3 showed that model farmers produced, on average, 32.88 quintals per hectare and 49.98 quintals per farmer, and non-model farmers produced, on average, 29.36 quintals per hectare and 30.54 quintals per farmer.

Table 3: Average Wheat Output by Groups of Farmers



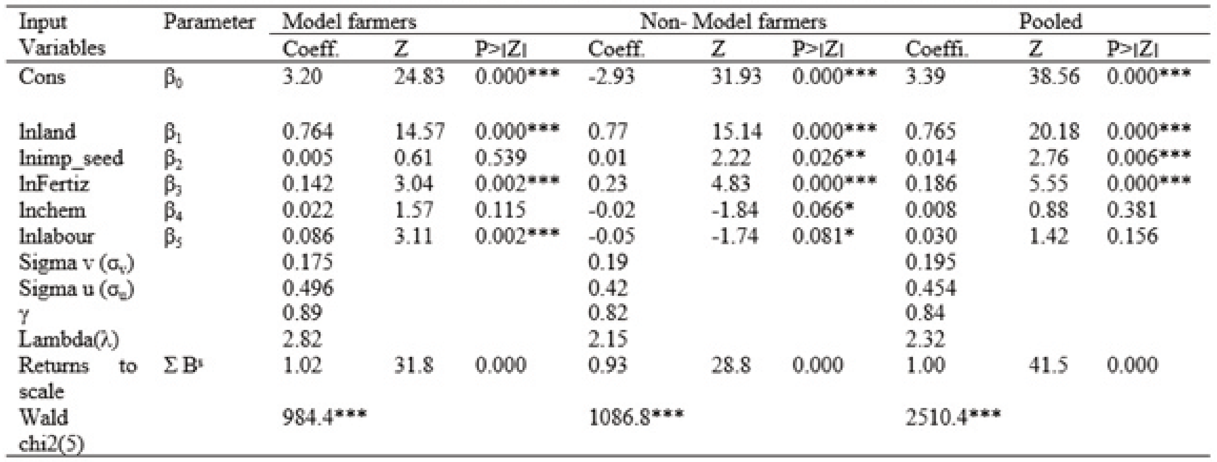
Groups	Obs	Mean	Min	Max	Total output	Total land(hec)	Output/hec
Model farmers	350	49.98	6	288	17,493	532	32.88
Non-model farmers	350	30.54	3	108	10,689	364	29.36
Overall	700	40.26	3	288	28,182	896	31.45

Note: hec=hectare, Output/hec=Output per total land, Mean=output per farmer

Econometric Result

Under this sub-section, econometric results of the stochastic production model, efficiency scores, and determinants of the inefficiency model were presented in tables 5, 6 and 7.

Table 5: Maximum Likelihood Estimates of the Cobb-Douglas Stochastic Production Frontier



Input Variables	Parameter	Model farmers			Non- Model farmers			Pooled		
		Coeff.	Z	P>|Z|	Coeff.	Z	P>|Z|	Coeffi.	Z	P>|Z|
Cons	β_0	3.20	24.83	0.000***	-2.93	31.93	0.000***	3.39	38.56	0.000***
lnland	β_1	0.764	14.57	0.000***	0.77	15.14	0.000***	0.765	20.18	0.000***
lnimp_seed	β_2	0.005	0.61	0.539	0.01	2.22	0.026**	0.014	2.76	0.006***
lnFertiz	β_3	0.142	3.04	0.002***	0.23	4.83	0.000***	0.186	5.55	0.000***
lnchem	β_4	0.022	1.57	0.115	-0.02	-1.84	0.066*	0.008	0.88	0.381
lnlabour	β_5	0.086	3.11	0.002***	-0.05	-1.74	0.081*	0.030	1.42	0.156
Sigma v (σ_v)		0.175			0.19			0.195		
Sigma u (σ_u)		0.496			0.42			0.454		
γ		0.89			0.82			0.84		
Lambda(λ)		2.82			2.15			2.32		
Returns to scale	ΣB^i	1.02	31.8	0.000	0.93	28.8	0.000	1.00	41.5	0.000
Wald chi2(5)		984.4***			1086.8***			2510.4***		

*The dependent variable is lnwheat output (lnwoutp_total), ***,** significant at 1% and 5% level

The table given below shows the mean technical efficiency scores of the model, non-model, and overall farmers.

Discussion

Discussion of Descriptive Results

Educated farmers can easily accept and implement agricultural extension services to increase production and ease communication with development agents. The findings of the descriptive results in Table 1 showed that 90.43% of farmers attended from basic education to grade 12 and 9.57% of them were illiterate (Never attended). Moreover, the descriptive result also indicates as the level of education increases, the average wheat output increases more for model farmers than non-model farmers. This implies model farmers produce more than non-model farmers as their level of education increases and this is more likely true that model farmers better adopt and practice modern technologies in agriculture, particularly wheat farming.

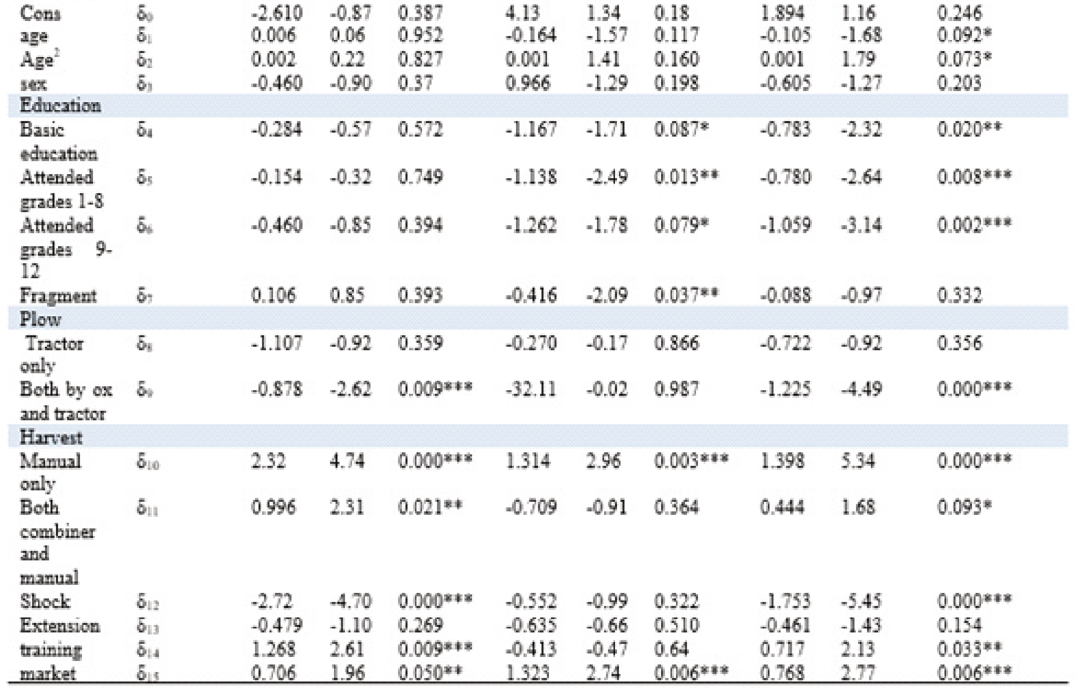
The descriptive analysis result further showed that model farmers had, on average, a total of 2.58 hectares of land used for agronomic practices, and out of these, 1.52 hectares of land which were fragmented into 2.56 plots were used for wheat farming. Similarly, non-model farmers had on average 1.74 hectares of cultivated land and only 1.04 hectares of land which was fragmented into 2.4 plots were used for wheat farming (Table 2). The t-test statistics show that the mean land used for wheat farming difference between model and non-model farmers is statistically significant at a 1% level (t= 8.6905, p= 0.0000).

Table 6: Mean Technical Efficiency Score by Groups of Farmers

Group of farmers	Obs	Mean TE	Std. Dev	Min	Max
Model farmer	350	0.81	0.146	0.32	0.965
Non-model farmer	350	0.79	0.148	0.23	0.962
Pooled	700	0.80	0.147	0.23	0.965

Source: Survey result, 2020

Table 7: Maximum Likelihood Estimates of the Inefficiency Variables



Ineffi. Variables	Parameter	Model farmers			Non- Model farmers			Pooled		
		Coeff.	Z	P>|Z|	Coeff.	Z	P>|Z|	Coeff.	Z	P>|Z|
Cons	δ_0	-2.610	-0.87	0.387	4.13	1.34	0.18	1.894	1.16	0.246
age	δ_1	0.006	0.06	0.952	-0.164	-1.57	0.117	-0.105	-1.68	0.092*
Age^2	δ_2	0.002	0.22	0.827	0.001	1.41	0.160	0.001	1.79	0.073*
sex	δ_3	-0.460	-0.90	0.37	0.966	-1.29	0.198	-0.605	-1.27	0.203
Education										
Basic education	δ_4	-0.284	-0.57	0.572	-1.167	-1.71	0.087*	-0.783	-2.32	0.020**
Attended grades 1-8	δ_5	-0.154	-0.32	0.749	-1.138	-2.49	0.013**	-0.780	-2.64	0.008***
Attended grades 9-12	δ_6	-0.460	-0.85	0.394	-1.262	-1.78	0.079*	-1.059	-3.14	0.002***
Fragment	δ_7	0.106	0.85	0.393	-0.416	-2.09	0.037**	-0.088	-0.97	0.332
Plow										
Tractor only	δ_8	-1.107	-0.92	0.359	-0.270	-0.17	0.866	-0.722	-0.92	0.356
Both by ox and tractor	δ_9	-0.878	-2.62	0.009***	-32.11	-0.02	0.987	-1.225	-4.49	0.000***
Harvest										
Manual only	δ_{10}	2.32	4.74	0.000***	1.314	2.96	0.003***	1.398	5.34	0.000***
Both combiner and manual	δ_{11}	0.996	2.31	0.021**	-0.709	-0.91	0.364	0.444	1.68	0.093*
Shock	δ_{12}	-2.72	-4.70	0.000***	-0.552	-0.99	0.322	-1.753	-5.45	0.000***
Extension	δ_{13}	-0.479	-1.10	0.269	-0.635	-0.66	0.510	-0.461	-1.43	0.154
training	δ_{14}	1.268	2.61	0.009***	-0.413	-0.47	0.64	0.717	2.13	0.033**
market	δ_{15}	0.706	1.96	0.050**	1.323	2.74	0.006***	0.768	2.77	0.006***

Source: Own computation 2020, ***, **, * significant at 1%, 5%, and 10% Note: The reference category for sex is male, for education is never attended, for the plow is plowing only by oxen, for harvest is harvesting only by tractor, for shock is "yes", for training is "yes" extension "yes" and for the market is "yes".

Regarding selected seed model farmers, on average, used 1.95 quintals of selected seed per hectare, and non-model farmers used 1.08 quintals of selected seed per hectare (Table 2). The mean selected seed use difference between model and non-model farmers is statistically significant at a 1 % level (t=8.2162, p=0.0000). This implies model farmers can afford more to purchase selected seeds than non-model farmers. But the mean of local seed used by model farmers per hectare is slightly lower compared to non-model farmers and the difference is statistically insignificant (t = -0.5825, p = 0.7198).

Fertilizer is another important input used by farmers to increase production and productivity. Accordingly, on average, 2.85 and 1.75 quintals of fertilizer per hectare were used by the model and non-model farmers respectively and the mean difference is also statistically significant (t=10.3856, p= 0.000). Labor (both family and hired labor) was another variable used in the production period. Farmers used to labor for plowing, sowing, weeding, harvesting, and threshing of wheat crops. All labor hours used for wheat farming were converted into a man-days (8 working hours as one man-day). Consequently, on average, model farmers utilized 29.58 laborers per hectare while non-model farmers utilized 20.33 laborers per hectare. This implies model farmers used more labor per hectare since they used hired labor to work for longer hours per day compared to non-model farmers (Table 2).

Regarding the wheat output of farmers, model farmers produced 49.98 quintals per head while non-model farmers produced 30.54 quintals per head. The t-test statistics showed that the mean difference in wheat output produced between model and non-model farmers (per farmer) is statistically significant at a 1% level (t=9.2097 p=0.000). This implies model farmers produced more compared to non-model farmers and this is because model farmers used more selected seeds, fertilizer, labor, and chemical to increase production compared to non-model farmers and better perform agricultural practices.

Econometric Result Discussion

The econometric result showed that Lambda (λ) value was 2.82 and 2.15 for model and non-model farmers respectively and suggested that the greater variation in wheat output is contributed by technical inefficiency rather than factor outside the control of farmers because λ is greater than one (Table5). Moreover, λ value greater than 1 also shows a good fit for the estimated model and the correctness of the distributional assumptions, half-normal (Ojehomon et al., 2013)

The value of this discrepancy ratio (γ) was found to be 0.89 and 0.82 for model and non-model farmers respectively and 0.84 for pooled ones. This coefficient, γ, is interpreted as about 89% of the variability in wheat output among model farmers and 82% among non-model farmers within the production year was contributed to technical inefficiency effect (u_i) which is under the control of farmers, while the remaining 11% and 18% variation in output was due to effects of random noise (v_i) which are outside the control of farmers for model and non-model farmers. This implies model farmers have better capability to mitigate factors outside their control, for instance, timely sowing, use of early mature crop varieties, constructing flood diversion channels, etc. than non-model farmers (Table 5).

Returns to scale is another important feature of the Cobb-Douglas production function. The econometric analysis indicated that model farmers exhibit constant returns to scale, this means if model farmers increase all input by 1% output also increases by the same percent while non-model farmers exhibit decreasing returns to scale. This implies if non-model farmers increase all input by 1% out will increase by less than 1% (Table 5) in the long run.

Regarding the interpretation of input variable coefficients for model farmers, land used for the wheat farm (lnland), Fertilizer (lnFertiz), and both family and hired labor (lnlabour) statistically significantly affect wheat output. Therefore, the econometric result showed that the coefficient of elasticity for lnland was 0.764 which is a 1% change in the size of land in hectares that will bring about a 0.764% change in wheat output at a 1% level of significance if all other covariates held constant. Similarly, a 1% change in fertilizer usage resulted in a 0.142% change in wheat output keeping all other covariate constants. Moreover, a percentage change in the use of more labor contributes to a change of 0.086% in wheat output (3.5). This finding is consistent with the works of Dessale (2019), Beshir (2016), and Asfaw et al. (2019).

However, for non-model farmers all input variables, that is, land, improved seed, fertilizer, chemical, and labor are statistically significant in affecting wheat output. Land has a coefficient of elasticity of 0.77, meaning, a 1% increase in the size of the land will result in a 0.77% in increase in wheat output, keeping all covariate constant and a 1% increase in the use of improved seed per hectare will bring about 0.013% change in wheat output as well as a percentage change in the use of fertilizer per hectare will result in 0.232% change in wheat output. But chemical and labor usage has a negative coefficient of elasticity and is interpreted as a 1% increase in the use of chemicals and labor per hectare will bring about a decrease in wheat output by 1.84% and 1.74% respectively. This implies chemicals and labor are under-utilized as land used for the wheat farm is small compared to model farmers (1.52 hectares for model and 1.04 hectares for non-model farmers) and non-model farmers need to give due attention to other types of inputs and agronomic practices (Table 5). A similar finding is also reported by Wassie (2014), Kaleb and Workineh (2016), and Gebrie and Madda (2018).

Regarding the technical efficiency scores of model and non-model farmers, the mean level of technical efficiency for model farmers was found to be 81% with minimum and maximum efficiency of 32% and 96.5% respectively. This score implies there is a wider disparity in technical efficiency among wheat-producing model farmers themselves. The mean score can be interpreted as farmers can increase wheat output by 19% without decreasing the existing input level but by only improving technical efficiency in the short run, but, in the long run, improving the existing level of technical efficiency of farmers alone may not lead to a significant increase in wheat output, it needs best alternative agronomic farming practices and modern technologies (Table 6).

On the other hand, the mean level of technical efficiency for non-model farmers was 79% with minimum and maximum scores of 23% and 96.2% respectively. Here is also a significant difference in technical efficiency within non-model farmers and there is also an opportunity for non-model farmers to increase output by 21% only by improving technical efficiency without reducing input in the short run. Despite the small numerical mean difference in technical efficiency between model and non-model farmers, the t-test statistics revealed that there is a significant difference in technical efficiency scores between model and non-model farmers at a 10% level (t=1.5903 p=0.0561). This implies that it is not very important to group farmers into model and non-model and provide differentiated extension services. Similarly, pooled (combined) farmers have meant technical efficiency score of 80% with minimum and maximum scores of 23% and 96.5% respectively (Table 6). Close to our finding, Getachew et al. (2020) find a 72% level of mean technical efficiency for wheat in the highland areas of the North Shewa region of Amhara. Similarly, Gebrie and Madda (2018) found a mean technical efficiency level for wheat is 79% in the highlands of the Simada district of the Amhara Region.

The potential output and wheat output gap which is resulted from technical inefficiency has computed by dividing actual output by technical efficiency scores (potential output) and the output gap is computed by taking the difference between potential output and actual output (Gebrie &Madda, 2018; Kibara, 2005). Thus, the potential output, actual output, and output gap for model farmers were 61.7, 49.98, and 11.72 quintals respectively. The potential output, actual output, and output gap for non-model farmers were 38.66, 30.54, and 8.12 quintals respectively. This implies model farmers have better potential to increase wheat output compared to non-model farmers by improving the efficient utilization of resources.

Identifying determinants of technical inefficiency of farmers is among one the study. Technical inefficiency of wheat production for model farmers is significantly affected by the mode of plowing, mode of harvesting, shock, training, and market. The technical efficiency of non-model farmers was affected by the level of education, land fragmentation, mode of harvesting, and market. The econometric results for model farmers showed that plowing wheat land both by oxen and tractors reduces technical inefficiency (increase technical efficiency) by 0.878 compared to plowing land only by oxen at a 1% level of significance but plowing land by an only tractor has no effect on technical inefficiency compared to plowing only by oxen (Table 7).

Model farmers, who did not experience shocks like disease, weed, and frost had lower technical inefficiency compared to those who confronted shock at a 1% significant level. This finding is consistent with the findings of Ologbon and Yusuf (2012). For non-model farmers, statistically, there is no difference in technical inefficiency scores whether a farmer experiences shock or not. Training is another important variable that affects the technical inefficiency of farmers. The econometric result depicted that model farmers who did not get training related to wheat production had higher technical inefficiency compared to those who were trained at a 1% level of significance (Table 7). This implies training is essential for model farmers to increase their technical efficiency score. This finding is in line with the works of Dessale (2019). However, training is insignificant in affecting the technical inefficiency of non-model farmers. This finding supports the findings of Kelemu et al. (2016).

The level of education affects the technical inefficiency of non-model farmers negatively and significantly. The econometric result indicated that non-model farmers who attended basic education, grade 1-8 and grade 9-12 had less technical inefficiency (technically more efficient) compared to those who were illiterate at 5% and 10% level significance. This finding agrees with the findings of Njeru (2010), Mesay et al. (2013), Tiruneh and Geta (2016), and a contradictory finding were reported by Assefa et al.(2019), Dessale(2019) and Musaba& Bwache(2014). This implies education improves the technical and managerial abilities of non-model farmers in wheat production (Table 7). Despite the positive effects of education in improving technical efficiency, it is statistically insignificant in affecting the technical inefficiency of model farmers. The findings reported by Kelemu et al. (2016) closely matched our findings.

Land fragmentation is hypothesized to affect technical inefficiency either positively or negatively. The econometric result revealed that the coefficient of land fragmentation is negative and significant for non-model farmers and positive and insignificant for model farmers. It can be interpreted as if land fragmentation increases by one plot, technical inefficiency of non-model farmers will decrease by 0.416 and is statistically significant at a 5% level. This finding agrees with the findings of Mesay et al. (2013) and against the findings of Assefa et al. (2019).

Harvesting is another variable that affects the technical inefficiency of wheat production by model farmers. The econometric result showed that harvesting wheat manually increases technical inefficiency or decreases technical efficiency compared to harvesting by only a combiner at a 1% level of significant and technical inefficiency increases for farmers who harvest wheat crops both by combiner and manually compared to those harvesting by only combiner at 5% level of significant (Table 3.7). Likewise, non- model farmers who harvested wheat manually only, their technical inefficiency increased compared to those farmers harvesting by combiner only, but for those non-model farmers who harvested by both combiner and manual, their technical inefficiency did not significantly differ compared to those farmers who harvested by combiner only (Table 7). This implies that to have better technical efficiency in the wheat production non- model farmers should harvest their wheat by combiner only as this mode of harvesting reduces wastage yield.

Marketing is the other variable that affects the technical inefficiency of wheat production and those model and non-model farmers who did not face marketing problems to wheat output had higher technical inefficiency (lower technical efficiency) in production compared to those who said "yes" to a marketing problem. This is more likely true that these farmers who did not face marketing problems produced less and used their wheat output for personal consumption rather than supplying for sales. This result is consistent with the findings of Tolesa et al. (2014), however, a different finding was reported by Mesay et al. (2013). Empirically, the mean efficiency of the model and non-model farmers who said "faced market problem or yes" is 85% and 83% respectively and the mean efficiency of model and non-model.

Table 8: Mean Efficiency Comparison by Market and Group of Farmers

Did you face a Marketing problem?	Model Farmer Freq.	Model Farmer %	Model Farmer Mean Efficiency	Non-Model Farmer Freq.	Non-Model Farmer %	Non-Model Farmer Mean Efficiency	t-test
Yes	134	38.29	0.85	143	40.86	0.83	1.5375
No	216	61.71	0.78	207	59.14	0.76	1.3133

Source: Own computation, 2020

Conclusion

The main objective of the study was to analyze technical efficiency differences between model and non-model smallholder wheat producer farmers. The descriptive result revealed that model farmers used better input compared to non-model farmers. The usage of better agricultural inputs makes model farmers produce an average of 49.98 quintals of wheat per head whereas non-model farmers produced an average of 30.54 quintals of wheat per head.

The econometric result also suggests that the greatest variation in wheat output is contributed by technical inefficiency rather than factor outside the control of farmers. The value of discrepancy ratio (γ) which indicates technical inefficiency variability was 89% and 82% for model and non-model farmers respectively while the remaining 11% and 18% variation in output was because of random noise (v_i) which are outside the control of farmers for model and non-model farmers. This implies model farmers have better capability to mitigate factors outside their control, for instance, timely sowing, use of early mature crop varieties, constructing flood diversion channels, etc. than non-model farmers.

Model farmer's wheat output was statistically significantly influenced by land used for wheat farm, fertilizer, and both family and hired labor with an expected sign while all input variables statistically significantly affect the wheat output of non-model farmers with expected coefficient sigh except chemical and labor. Similarly, model farmers’ technical inefficiency in wheat farming was statistically significantly determined by the mode of plowing, mode of harvesting, shock, training, and marketing, and that of non-model farmers' technical inefficiency in wheat farming was significantly determined by the mode of harvesting, level of education, land fragmentation and marketing.

Regarding the mean technical efficiency score, model farmers scored 81% and non-model farmers scored 79% and the overall farmers scored 80% suggesting that there is room to increase the technical efficiency of wheat farming if farmers improve the overall use of scarce resources. The technical efficiency scores indicated that there is a slight difference in the mean technical efficiency scores between model and non-model farmers. However, in terms of wheat output produced per farmer, there is a wide gap between model and non-model farmers. This implies that it will be better to increase wheat output produced by non-model farmers by improving input usage and then technical efficiency values will be increased for both farmers' groups, otherwise grouping farmers into model and model and providing them differentiated extension services better contribute to output variation than technical efficiency improvement.

Thus, training, encouraging farmers to plow the land with both oxen and tractor and harvest with combiner to reduce wastage, and strategic plan to mitigate factors beyond the control of farmers, education, improvement of land fragmentation problems (clustering), use of improved seed and chemicals need to get better attention for non-model farmers to increase production and sufficiently provided for both model and non-model farmers to improve technical efficiency scores.

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Author Contributions

Meshesha Zewdie came up with the idea and wrote the proposal, as well as designed data collection techniques and wrote the first draft. Dessaleng Shamebo (Ph.D.) handled the proposal and editorial issues, analyzed the data, and prepared the final draft. There is no conflict of interest among researchers.