TECHNICAL EFFICIENCY OF POTATO PRODUCTION BY SMALLHOLDER FARMERS: THE CASE OF DINSHO DISTRICT, BALE ZONE OF OROMIA REGION, ETHIOPIA

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DEDICATION

I dedicate this thesis manuscript to the whole members of my family especially to my lovely sister Wegayehu Jenbere, for her heartfelt ambition to my success in my academic journey.

STATEMENT OF THE AUTHOR

By my signature below, I declare and affirm that this Thesis is the result of my own work. I have followed all ethical and technical principles of scholarship in the preparation, data collection, data analysis and compilation of this thesis. Any scholarly matter that is included in the Thesis has been given recognition through citation and acknowledgments.

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BIOGRAPHICAL SKETCH

The author was born in Gasera district, Bale Zone of Oromiya Regional State, on September 23, 1992 G.C, from his mother Eniye W/Semayat and his father Jenbere Senbeta. He attended his elementary education at Gasera elementary school. After completion of his elementary education, he then joined Gasera secondary school in the same town and completed his high school education in May 2008 G.C. After completion of his high school education, he joined Jimma University in September 2012 G.C and graduated with B.Sc. Degree in Agricultural Economics on June 26, 2014 G.C. After graduation, in October 2014 G.C he joined Madawalabu University as a Graduate Assistant in the Faculty of Agriculture, at the Department of Agricultural Economics. He has served for two years as a graduate Assistant I and II until 2015 G.C. By the year 2016 G.C he joined Haramaya University, school of graduate studies to pursue his MSc. degree in Agricultural Economics.

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ACRONYMS AND ABBREVIATIONS

AE	Allocative Efficiency
ARARI	Amhara Regional Agricultural Research Institute
CRS	Constant Return to Scale
CSA	Central Statistical Agency
DDANRO	Dinsho District Agricultural and Natural Resource Office
DEA	Data Envelopment Analysis
EE	Economic Efficiency
EIAR	Ethiopia Institute of Agricultural Research
FAO	Food and Agriculture Organization
MoFED	Ministry of Finance and Economic Development
OPH	Output Harvested
RSCD	Research and Community Service Directorate
SFA	Stochastic Frontier Analysis
SPF	Stochastic Production Frontier
TE	Technical Efficiency
TLU	Tropical Livestock Unit
WFP	World Food Programme

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Technical efficiency of potato production by smallholder farmers: The case of Dinsho district, Bale Zone of Oromia Region, Ethiopia

ABSTRACT

This study was aimed to analyze technical efficiency of potato production by smallholder farmers in Dinsho district, Bale zone of Oromia region. The study used a cross sectional data obtained from a field survey using structured questionnaire from a random sample of 149 smallholder potato producers in the study area. The hypothesis test result showed that Cobb-Douglas production function was found to satisfactorily fit the data. A Cobb-Douglas stochastic frontier production analysis approach with the inefficiency effect model was used to simultaneously estimate technical efficiency and identify the determinants of efficiency variations among potato producer farmers. The maximum likelihood parameter estimates showed that potato output was positively and significantly influenced by area, quantity of urea fertilizer and quantity of seed used. The positive coefficients of these parameters indicate that increased use of these inputs will increase the production level of potato in the study area. The discrepancy ratio, γ, which measures the relative deviation of output from the frontier level due to inefficiency was 0.76. This implies that about 76 percent of the variation in potato output among the sample respondents was due to technical inefficiency effects. The result of the study further showed significance differences in technical efficiency among potato producers in the district. The single stage estimation result showed that the mean technical efficiency of the farmers was found to be 0.74 and ranged between 0.23 and 0.98. This tells that there exists an option for farmers to increase the level of potato output on average by about 24 percent through exploiting the existing local practices and technical knowledge of the relatively efficient farmers. The estimated SPF model together with the inefficiency parameters shows that education level, land ownership, fertility status of potato plots and frequency of extension contact negatively and significantly affected technical inefficiency of potato production while land fragmentation positively and significantly affected it. Therefore, any development program aimed at improving technical efficiency of potato production should focus on the above mentioned factors.

Key words: Dinsho, Potato, Stochastic Frontier Analysis, Technical Efficiency, Cobb-douglas

1. INTRODUCTION

1.1. Background of the Study

Agriculture is the most significant contributor to Ethiopia's national economy and it accounted for 38.8% of GDP ((UNDP, 2016). It employs about 85% of the total labour force (MoFED, 2013).

Potato (Solanum tubersum L.) is a root crop and ranks first in its volume of production and consumption followed by cassava, sweet potato and yam in Ethiopia (Tiruneh *et al*., 2017). It has great potential when it comes to food security (UNDP, 2014). Thus, potato is among the crops that have increasingly gained importance for overcoming food insecurity problems in the country.

Ethiopia is one of the countries where the potential of this crop is increasingly being realized as witnessed by growing interest in this crop by private investors and policy makers. In recent years, the production of this crop is expanding because of availability of improved technologies, expansion of irrigation structure, increased market value, and production systems diversification produced under rainy season, irrigation, residual moisture, short rains and recessed land (EIAR and ARARI, 2013).

In Ethiopia, potato production could fill the gap in food supply during the hungry months of July to August before the grain crops are being harvested. Potato in Ethiopia was planted in around 66,923.33 hectares producing an estimated total production of 9,214,031.85 quintals. In Meher season of 2016/17, about 1,197,018 smallholder farmers were reported growing potato (CSA, 2016/17). Thus, potato is an important crop for smallholder farmers in Ethiopia, serving as both a cash and food security crop. It is one of the root crops widely grown in the country with the highest rate of growth because increasing demand and emerging markets are providing great opportunity for resource-poor farmers to generate additional income (EIAR and ARARI, 2013). As a result, potato production plays an important role in the economy of Ethiopia.

In the study area, potato is one of food security root crop. According to the Dinsho district's agricultural and natural resource office data (2017), more than 9200 people have received relief food assistance only for the second half of 2017 fiscal year. In this regard, production of potato has great food security potential in the district where large numbers of people are depending on relief food assistance. Area coverage of potato cultivation has increased by 40.29 percent from 2016 to 2017. In the same period, the production level has increased by 43.61 percent.

Furthermore, potato has great marketing potential in the district. Farmers chose to increase the production and marketing of these enterprises, among others based on the potential that the crops had in the study area (DDANRO, 2017).

Potato has a short cropping cycle and relatively large production per unit area in a given time. It is a cash crop of the future for the densely populated East and Central African highlands, with a high potential to raising the livelihoods of smallholders. However, the average yield in Ethiopia reaches only 7 tons/ha when the potential for smallholder is around 25 tons/ha (EIAR and ARARI, 2013).

Thus, as it is indicated above, among other crops, farmers in the study area are interested to increase the production and marketing of potato crop. Given the fact that farmers are resource constrained, increasing potato production for its food security and marketing potential requires efficient utilization of the existing resources. As a result, analyzing the efficiency of production is the appropriate way to identify if resources are being used optimally. However, there is no evidence as to the level of technical efficiency of potato production by smallholder farmers in the district. Thus, the aim of this research is to determine if the farmers' choice of potato production in the district can be justified empirically.

1.2. Statements of the Problem

Ethiopia is predominantly an agricultural country having about 85 percent of its rural population involved in agricultural food production (MoFED, 2013). Nevertheless, FAO/WFP (2012) reported that Ethiopia have food demand exceeding its local production. This indicates that Ethiopia lags far behind in providing food for her ever increasing population. Ethiopia,

therefore, is faced with a great challenge in terms of inadequacy of food supply. This has increased the country's dependence on external food aid to meet its population food demand.

In the last 10 years, potato productivity has progressed from 7 to 11 tons/ha. Nevertheless, the current area cropped with potato (about 0.16 million ha) is very small and the average yield is below 10 tons/ha-far below the country's potential (EIAR and ARARI, 2013).

Though agriculture is still remains to be the most important sector of the Ethiopian economy its performance has been unsatisfactory and unable to fulfill the requirement of the ever increasing number of mouths with sall development endeavors. This is mainly attributed to the poor use of modern inputs such as fertilizers, improved seeds and extension services which partly explain the less productivity of the sector and apart from this, the internal efficiency difference of the farmers in using the available agricultural resources such as land and labor.

One of the significant contributors for its deprived performance is the low productivity of the sector over the past years (Alemayehu *et al*., 2012). Such low productivity leads to increasing poverty and food insecurity of rural farm households.

The available data in the study district also hinted that farmers were resource-constrained, and efficiency of potato producer households were affected by different socio-economics, demographic, institutional and other factors. Productivity of potato could be increased either by introducing new technologies or improving the efficiency of inputs at the existing technology. However, the mere introduction of new technology could not bring the expected result without knowing the existing level of technical efficiency of inputs.

Analyzing the efficiency of production is the appropriate way to identify if resources were being used optimally. However, so far, there was no any empirical study undertaken in the study area. The conditions of resource scarcity, low productivity of potato and food insecurity problem have leaded me to examine technical efficiency of potato production in the district.

1.3. Objectives of the Study

The general objective of this study was to analyze technical efficiency of potato production by smallholder farmers in Dinsho district of Bale zone.

The specific objectives of the study were:

1. To measure the technical efficiency level of potato production in the study area; and
2. To identify the sources of technical efficiency differences in the study area.

1.4. Significance of the Study

Knowledge of the technical efficiency level of sample farmers in the study area will help to know as to what extent production can be increased in the District if the level of efficiency is improved given the existing level of input use. Conversely, as to what extent inputs can be minimized if the level of efficiency is improved at the existing level of output. This helps to evaluate the effect of previous development programs in increasing the efficiency level of the farmers in the production of potato.

Furthermore, farm level technical efficiency estimates will also help to identify the efficiency level of each potato producing farmers. Based on the efficiency level of each farmer, the determinants of efficiency will be identified. Identification of the determinants of efficiency is important for various planning and policy purposes.

Lastly, this with other previous studies will be used as input for future empirical studies in the area of efficiency. The beneficiaries of this study results will be farmers, researchers, governmental organization, non-governmental organizations and others involved in potato production improvement centers.

1.5. Scope and Limitations of the Study

This study focused on technical efficiency of potato production in one *woreda*, using cross sectional data of the 2016/17 production year collected from 149 potato producing smallholder farmers.

The study was also limited to the analysis of technical efficiency in the production of potato. Other crops were not included in the estimation of efficiency scores. The other limitation was related to the methodology used. The efficiency scores of the frontier method were only relative to the best performing farmers in the sample. Thus, efficiency scores might be reduced if more efficient farmers were included in the study. Likewise, it could also increase if less efficient farmers were included (Coelli *et al*., 1998).

The use of cross sectional data in technical efficiency analysis only reflects farmers' circumstances on the given production season. This may be affected by the specific climate of the year, as agriculture in the area is much vulnerable to externalities such as unpredictable and variable rainfall, disease and pest occurrences, etc. As a result, the use of cross sectional data may affect the findings of the study since it does not capture the inter-temporal differences in efficiency of farmers.

1.6. Organization of the Thesis

The thesis is organized into five chapters. The first chapter presents the introductory part. The second chapter deals with review of literature which includes definition and concepts of technical efficiency, conceptual framework of technical efficiency and empirical studies made on technical efficiency in different countries. Description of the study area, types and sources of data, sampling design, data collection and methods of data analysis are presented in chapter three. Chapter four presents the results and discussion of descriptive and econometric models. Finally, summary, conclusions and recommendations based on the results of the study are presented in chapter five.

2. LITERATURE REVIEW

2.1. Concepts of Production Efficiency

The area of efficiency analysis becomes the central issue of performance analysis since the work of Farrell (1957). Many scholars have used efficiency and productivity interchangeably and consider both as the measure of performance of a given decision making unit. However, these two interrelated terms are not precisely the same (Coelli, 1995; Coelli *et al*., 2005). Based on the above authors the different terms in efficiency analysis are defined as follows.

Productivity: It is an absolute concept, which is measured by the ratio of output(s) to input(s). The measures of productivity involves either total factor productivity, which is a productivity measure involving all factors of production or other traditional measures of productivity such as labor productivity in a factory and land productivity (yield) in farming which are often called partial measures of productivity. These partial productivity measures can provide a misleading indication of overall productivity when considered in isolation (Coelli *et al*., 2005).

Efficiency: It is a relative concept and measured by comparing the actual ratio of output to inputs with the optimal ratio of output to inputs,which is represented by production frontier. The concept and measurement of efficiency relies on the specification of a production function (Coelli *et al*., 2005).

Production function: Represents the maximum output attainable from the use of a given level of inputs. It describes production performance and productivity is the measure of it.

Technical efficiency: Refers to the ability of a farmer to produce a maximum output from a given set of inputs or it is the ability of a farmer to produce on production frontier. A producer is technically efficient if an increase in any output requires a reduction in at least one other output or an increase in at least one input. The difference between productivity and technical efficiency is a farmer may be technically efficient without attaining optimal

productivity level. The farmer can attain the maximum possible productivity by exploiting scale economies (Coelli *et al*., 2005).

Allocative efficiency: Is the ability of a farmer to use inputs in optimal proportion, given their respective prices and the production technology. In other words it is the ability of the farmer to produce a given level of output using cost minimizing input ratios. The use of an input is allocatively efficient if the value of marginal product of the input is equal to its price (Coelli *et al*., 2005).

Economic efficiency: It is the optimal input mix to produce any given level of output that minimizes the cost of production. It is the product of technical and allocative efficiency. A farmer is economically efficient if it is both technically and allocatively efficient (Farrell, 1957; Coelli, 1995).

2.2. Theoretical Review for Efficiency of Production

The farmers output can be increased through increased inputs, increasing productivity of inputs and the combination of the two. Hence, efficiency is a central issue in production economics helping as a guide for allocation of resources (Farrell, 1957). Productivity improvements can be achieved in two ways. One can either improve the state of the technology by inventing new technology which leads to an upward shift in the production frontier or alternatively one can improve efficiency of the farmers to use the existing technology more efficiently. This would be represented by the firms operating more closely to the existing frontier. Therefore, it is evident that increase in productivity achieved through either technological progress or efficiency improvement so that the policies required to address these two issues are likely to be quite different (Coelli, 1995).

According to Farrell (1957), efficiency can be measured using either input-oriented or output-oriented approaches. The input-oriented approach addresses the question by how much can input quantities be proportionally reduced without changing the output quantities produced while the output-orientied approach addresses the question by how much can output be increased without increasing the amount of input use that is utilizing the given input more efficiently. In this study, out-put oriented approach was used since farmers are

using low level of inputs. Brief explanations of these approaches are given bellow based on Coelli *et al*. (1998).

2.2.1. Input-Oriented Efficiency Measure

The input oriented approach addresses the question "by how much a production unit can proportionally reduce the quantities of input used to produce a given amount of output?" (Coelli *et al.*, 1998)**.**

Farrell (1957) illustrated Input- oriented measure of farm efficiency using two firms which use two inputs of production, capital (K) and labor (L), to produce a single output (Y), and face a production function, y = F (K, L), under the assumption of constant returns to scale. The assumption of constant return to scale will help us to present all necessary information on a simple isoquant.

The analysis of efficiency carried out by Farrell (1957) could be clarified in terms of figure 1.

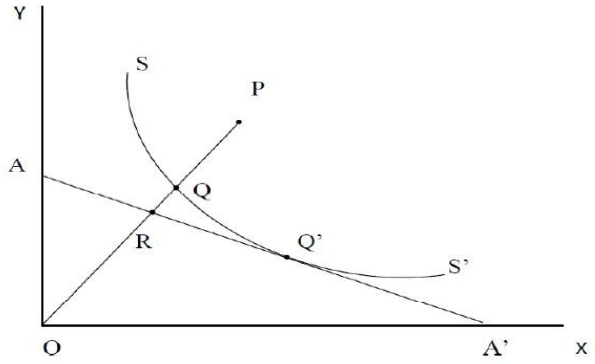

Figure 1: Input-oriented measures for efficiency
Source: Adopted from Coelli *et al.* (2005)

Suppose a firm using two factors of production to produce a single product under conditions of constant returns to scale (CRS). The isoquant SS' characterizes the technological set that obtains the minimum combination of inputs needed to produce a unit of output. Therefore, every combination of inputs along the unit isoquant is considered as technically efficient.

For this reason, Q and Q' are two technically efficient points and P is inefficient point. Consider a firm at point P, using quantities of input to produce a unit of output, the technical

inefficiency of this firm could be explained by distance QP which QP is the input package that the firm at point P could save without decreasing the amount of output. The ratio QP/OQ indicates the percentage by which all inputs need to be reduced to achieve technical efficiency production. Hence, the technical efficiency (TE) of the producer under analysis (1-QP/OP) would be presented by the ratio OQ/OP.

$$TE = OQ/OP \quad (1)$$

2.2.2. Output-oriented Measure

Output oriented approach addresses the question "by how much can output be increased without increasing the amount of inputs used" (Coelli *et al.,* 1998).

Figure 2 below illustrates the output oriented approach of efficiency measurement using a production possibility curve that shows the possible combination of two outputs (Y_1 & Y_2) one can produce from a given input X and the level of technology.

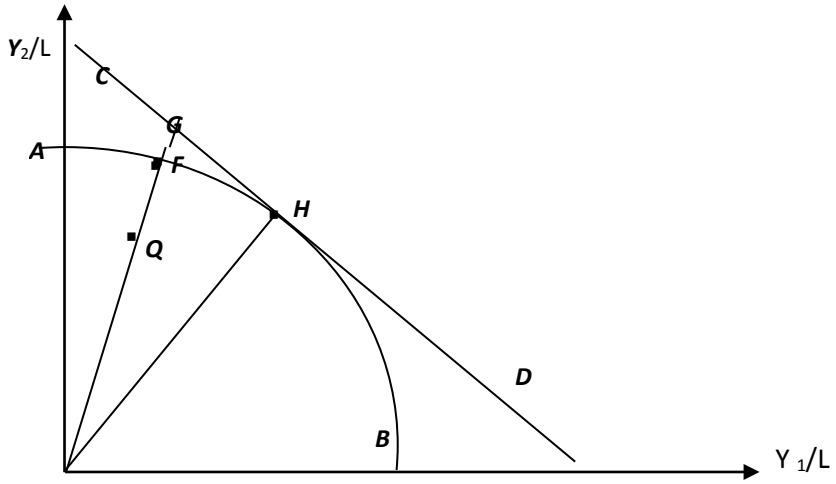

Figure 2: Measure of Efficiency from an Output orientation

In figure 2 AB shows the production possibility curve. Since the production possibility curve represents the upper bound of production possibilities, producers can be located either on the curve (like points F and H) or below it (like point Q), but not above it. Points below the curve correspond to inefficient firms.

The Farrell's output-oriented efficiency measure is defined as follows. In the figure the distance QF represents technical inefficiency. That is the amount by which outputs could be

increased without requiring extra input. Hence, at point Q, Farrell's measure of output-oriented technical efficiency at point Q represented by the ratio of distance OQ to OF.

$$TE_Q = OQ/OF$$

The value of technical efficiency lies between 0 and 1.

2.3. **Methodological Review for Measuring Technical Efficiency**

There are two analytical approaches that can be used to measure efficiency in production: non-parametric and parametric frontier approaches. A parametric approach is represented by stochastic frontier, while Data Envelopment Analysis (DEA) for non-parametric approach. There are strengths and weaknesses to each approach, which may influence the choice of approaches. The frontier methodology has been widely used in production analysis mainly due to its consistency with the text book definition of a production, profit or cost functions (i.e. with the notion of maximization or minimization) (Thiam *et al.,* 2001).

2.3.1. Non-parametric Frontier Models

DEA is both non parametric and non-stochastic model and may be either input oriented or output oriented. Both input oriented and output oriented DEA produces same efficiency estimate for a farm firm under assumption of constant returns to scale in production.

DEA technique to measure technical efficiency has not been applied frequently in Agriculture. (Coelli *et al.,*1995). However, a relatively small but growing number of agricultural applications have used the DEA approach to frontier estimation (Shafiq and Rehman, 2000). To the researcher's best knowledge, there are only few studies like Chavas and Aliber (1993) that are conducted to analyze technical, allocative and economic efficiencies in Agriculture using DEA.

Generally most researchers, among others Coelli *et al*.,(1998), Mohammad and Premachandra (2003), Thiam *et al*. (2001), Ajibefun (2002) and Parikh and Shan (1996) concur that stochastic frontiers are probably going to be more proper than DEA in agricultural applications of efficiency analysis.

The model avoids the imposition of unwarranted structures on both the frontier technology and the inefficiency component that might create distortion in the measurement of efficiency (Fare *et al*., 1985).

Charnes *et al*. (1978) proposed a model which had an input-oriented constant return to scale (CRS) model of DEA.

$$\max_{\mu,v} (\mu' y_i$$

Subject to: $v' x_i = 1$

$$\mu' y_j - v' xj \leq 0, \qquad j = 1, 2...N$$

$$\mu, v \geq 0$$

Where, Y is MX*N is output matrix

X is KX*N is input matrix

μ is an M*1 is vector of output weights and

v is a K*1 is vector of input weights

$v' x_i = 1$ is the restriction to avoid infinite solution to the problem. Using the duality theory in linear programming, one can derive an equivalent envelopment from this problem:

$$\min_{\theta\Lambda} \theta_1$$

Subject to: - $-Y_i = Y_\Lambda \geq 0,$

$$\theta_{xi} - X_\Lambda \geq 0,$$

$$\Lambda \geq 0,$$

Where, θ is a scalar and Λ is a N x 1 vector of constants. The value of θ obtained will be the efficiency score for the i^{th} firm. It will satisfy $\theta \leq 1$, with a value of 1 indicating a point on the frontier and hence a technically efficient firm (Farrell, 1957).

The non-parametric DEA model has the following advantage and disadvantages. According to Coelli *et al*., (1998) summarized DEA has the following advantages; it can handle multiple inputs and multiple outputs, it doesn't require an assumption of a functional form relating input to outputs, it doesn't require a priori assumption with regard to the distribution of inefficiency parameter as in the case of parametric frontier models and it is unit invariant.

However, there are many drawbacks that are related to DEA. The main criticism of DEA is that it assumes all deviations from the frontier are due to inefficiency. Due to this, non-parametric frontier methodology may overstate inefficiencies and hence outliers may have profound effect on the magnitude of inefficiency (Llewelyn and Williams, 1996).

In addition, in DEA do not consider the possible influence of measurement errors and other noise upon the frontier. All deviations from the frontier are assumed to be the result of technically inefficiency.

2.3.2. Parametric Frontier Models

The parametric model of efficiency analysis uses econometric techniques and can be classified into deterministic and stochastic frontier. The deterministic model assumes that any deviation from the frontier is due to inefficiency, while the stochastic approach allows for the statistical noise.

2.3.2.1. Deterministic frontier model

The deterministic frontier model uses econometric techniques to estimate the parameters of the pre-specified functional forms. Aigner and Chu (1968) were the first researchers to estimate a deterministic frontier production function using Cobb-Douglas production function. According to them the model is defined as follows.

$$\ln (Y_i) = x_i\beta - u_i \quad , \quad i = 1,2, ...N.$$

Where, 1n (Y_i) = the natural logarithm of the (scalar) output for the ith firm;

x_i = a (k + 1) a row vector, whose first element is "1" and the remaining x elements are the logarithms of the k input quantities used by the i^{th} firm;

$\beta = (\beta_0, \beta_1 ... \beta_k)$ is a (k+1) column vector of unknown parameters to be estimated.

u_i =is a non-negative random variable associated with technical inefficiency, representing the shortfall of actual output from its maximum possible value.

Therefore, the ratio of the observed output for the i^{th} firm, relative to the potential output, defined by the frontier function, given the input vector, x_i, is used to define the technical efficiency of the i^{th} firm.

$$TE_i = \frac{Y_i}{exp\ (x_i,\beta)} = \frac{exp\ (x_i\,\beta - U_i)}{exp\ (x_i,\beta)} = \exp\ (-U_i)$$

In deterministic model all deviations from the frontier are assumed to be the result of technical inefficiency and no account is taken of any measurement errors or any statistical noise (i.e. omission of relevant variables from the vector x_i) (Coelli *et al*., 1998).

Hence when there is high random error on the data or where there are few outliers, the inefficiency estimates will be exaggerated as compared to other models, which take into account random errors. Neff *et al*., (1993) and Apezteguía and Garáte (1997) in their comparative studies of frontier models found that deterministic frontier model generate higher technical inefficiency indices than stochastic frontier model. The reason could be that the proportion of deviation due to noise might be less than the deviations due to inefficiency.

2.3.2.2. Stochastic frontier model

The stochastic frontier production function was independently proposed by (Aigner *et al*., 1977; Meeusen and Von den Broeck, 1977). The original specification involved a production function specified for cross-sectional data which had an error term with two components, one to account for random effects and another to account for technical inefficiency. Hence, stochastic estimations of technical efficiency incorporate a measure of random error, which is one component of the composed error term of a stochastic production frontier. This model acknowledges the fact that factors, which are outside the farmers‟ control, can also affect the level of output. So it made possible to find out whether the deviations in production from the frontier output is due to firm specific factors or due to external random factors. This model can be expressed in the following form:

$\ln (Y_i) = x_i\,\beta + v_i - u_i$

Where, v_i = random error term of the model, and other variables are defined as in equation

u_i = is a non-negative random variable associated with technical inefficiency in production of firms in the industry involved.

1n (Y_i) = the natural logarithm of the (scalar) output for the i^{th} firm; x_i = a (k + 1) a row vector, whose first element is "1" and the remaining x elements are the logarithms of the k input quantities used by the i^{th} firm; $\beta = (\beta_0, \beta_1 ... \beta_k)$ is a (k+1) column vector of unknown parameters to be estimated.

The maximum likelihood estimates of the parameters of the frontier model are estimated, the variance parameters are expressed in terms of the parameterization:

$\sigma_s^2 = \sigma_v^2 + \sigma^2$ and

$\gamma = \sigma^2 / \sigma_s^2 = \sigma^2 / \sigma_v^2 + \sigma^2$

Where, σ^2 - is the variance parameter that denotes deviation from the frontier due to inefficiency

σ^2_v - is the variance parameter that denotes deviation from the frontier due to noise.

σ_s^2 - is the variance parameter that denotes the total deviation from the frontier.

The parameter γ has a value between 0 and 1. A zero value of γ 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.

Battese and Coelli (1988) pointed out that in the prediction of farmers level technical efficiencies which the best predictor of $\exp(-U_i)$ is obtained by:

$$E[\exp(-U_i)/ei] = \frac{1 - \phi(\sigma_v + \gamma_{ei}/\sigma_v)}{1 - \phi(\gamma_{ei} / \sigma_v)} \exp(\gamma e_i + \sigma^2/2)$$

Where $\sigma_v = \sqrt{\gamma\,(1-\gamma)\sigma_s^2}$

$ei = \ln(Y_i) - X_i\beta$

$\phi(.)$ = is the density function of standard normal random variables.

The random error, V_i, accounts for measurement error and other factors, such as the effects of weather, strikes, chance, etc., on the value of the output variable, together with the combined effects of unspecified input variables in the production function.

Aigner *et al.* (1977) assumed that the V_is were independently and identically distributed (i.i.d) normal random variables with mean zero and constant variance, σ_v^2, independent of the u_i that were assumed to be i.i.d. exponential or half-normal random variables. The primary advantage of the stochastic frontier production function is that it enables one to estimate farm specific technical efficiencies. The measure of technical efficiency is equivalent to the production of the i^{th} farm to the corresponding production value if the farm effect u_i were zero. It has an ability to decompose the total error term into a one-sided efficiency parameter and random variable consisting of uncontrolled factor.

It is the only method that identifies between random factors and inefficiency (Kutaula, 1993). When the symmetric random error 'V_i' dominates 'ε_i' the stochastic frontier and the deterministic frontier results diverge. When 'U_i' is unimportant the stochastic procedure suggests that all variations from the frontier be due to random error rather than any technical inefficiency, while such variation is contributed to technical inefficiency by the deterministic approach. Therefore, the ranking of individual firms obtained with the two approaches is strongly correlated (Ekanayake *et al.*, 1987).

However, the estimation of efficiency using stochastic method requires a prior specification of functional form and needs distributional assumptions (half-normal, gamma, truncated, etc.) for the estimation of U_i, which cannot be justified given the present state of knowledge (Coelli *et al.*, 2005).

2.4. Some Methodological Considerations

The purpose of this section is to discuss some methodological considerations that should be kept in mind when conducting efficiency studies. The first important issue has to do with the choice between a non-parametric and parametric specification, keeping in mind that the latter can be deterministic or stochastic. SPF from parametric approach and DEA from nonparametric approach are the two main models in the empirical efficiency studies. As noted by Coelli *et al*. (1998), the stochastic frontier is considered more appropriate than DEA in agricultural applications especially in developing countries where the data is likely to be influenced by measurement error and the effects of weather conditions, disease etc.

Gong and Sickles (1992) concluded that, due to lack of empirical analysis, little can be said about how non-parametric frontiers perform in relation to parametric models. However, several papers had compared the performance of different parametric frontier models, using the same data set, for developing as well as developed countries. Stochastic models yield a somewhat higher average TE than their deterministic counterpart. It was argued with justification that stochastic models are more reliable than deterministic models because the former accounts for statistical noise (Coelli, 1995).

A second mater that arises, which is not unique to frontier studies, concerns the choice of functional form in parametric models. The pertinent question is when interpreting parametric studies in the possible sensitivity of the efficiency measures to the choice of functional form. In one of the few studies examining the impact of functional form on efficiency, Kopp and Smith (1980) stated "functional specification has a discernible but rather small impact on estimated efficiency". One can argue, however, that an integral part of applied production analysis should be the evaluation of the impact of functional form on the key results of the study. The methodological foundation for this type of evaluation stems from developments in the econometric literature dealing with specification tests (Greene, 1990a).

Another important issue that concerns the stochastic frontier models is the distributional assumptions made for composed error term. Much of the literatures to date has followed the half normal distribution for one-sided (inefficiency) error term, as originally proposed by (Aigner *et al*., 1977), despite the fact that more flexible distributions are available. Greene (1990b) concluded that, for his data, efficiency levels were essentially the same for the half normal, truncated normal and exponential distributions while the gamma model yielded higher efficiency. The symmetric error term is usually assumed to independently and identically follow normal distribution.

The fourth methodological concern has to do with the use of the one-step or two-step procedure to examine the determinants of efficiency. Kalirajan (1991) has defended the two step procedure by stating that socioeconomic attributes have a roundabout effect on production and, hence, should be incorporated into the analysis indirectly. In contrast, Ray (1985) has argued that the two step procedures is justifiable if one assumes that the production function is multiplicatively separable in what he calls discretionary and non-discretionary inputs. Critics

of this approach contend that the socioeconomic variables should be incorporated directly in the production frontier because such variables may have a direct impact on efficiency (Battese *et al*., 1989).

2.5. Some Related Empirical Studies on Technical Efficiency

Most empirical studies of technical efficiency targeted identifying the sources of efficiency difference among producers. This is because the measurement of efficiency level only has no policy implication unless the real causes of efficiency differences are identified. Frontier production function models have been applied in a considerable number of empirical studies both in agriculture and non-agricultural sectors since the groundbreaking work of Farrell. In addition, as noted by Coelli *et al*., (1998), the stochastic frontier approach is only well developed for single-output technologies, unless one is willing to assume a cost-minimizing objective. Some Selected related empirical studies were reviewed below to see the method being followed in efficiency study.

Khuda *et al*. (2006) using stochastic frontier production function and adopting Cobb-Douglas production function in Pakistan Punjab specified a mean technical efficiency level of 76% indicating that there exist a large potential to increase potato production. Results also indicated that age of the respondents, consulting extension staff and cost of plant protection measures were positively related with technical efficiency. Finding of the study suggested that by improving technical efficiency, food security problem could be handled to a great extent with available technology and resources.

Temesgen and Ayalneh (2005) examined the technical efficiency of farmers in the production of irrigated potato in Districts of Awi Zone in North-western Ethiopia. The Translog stochastic frontier production function was used for data analysis. Technical efficiency of farmers was estimated independently for the farms under modern irrigation schemes and traditional irrigation schemes. The mean level of technical efficiency was found to be 77 percent and 97 percent respectively for modern and traditional schemes. Therefore, improving the level of efficiency could raise productivity under modern schemes, whereas improving productivity under traditional schemes needs introduction of new technology as the farmers‟

level of production has approached the frontier. Irrigation experience, commodity rate of production and size of livestock are found to be the important variables that determine the level of efficiency.

Abdullah *et al.* (2006) estimated the technical efficiency in potato production by employing the Cobb-Douglas stochastic production frontier approach in Punjab District, Pakistan. The results of the study indicated that potato farmers are 84 percent technically efficient, implying significant potential in potato production that can be developed. By shifting the average farmer to the production frontier, the average yield would increase from 8.33 tons per acre to 9.92 tons per acre using the available resources. The additional quantity of potatoes gathered through efficiency improvements would generate $16.51 million of revenue each year.

Consultation with extension workers significantly contributes to the improvement of technical efficiency and implies that the extension department should be one of the major targeted variables from the policy point of view in order to improve technical efficiency in potato production.

Maganga (2012) examined empirically the technical efficiency of Irish potato producers of Dedza district, Central Malawi using cross section data from 200 farmers. Translog stochastic production frontier model was used to predict farm level technical efficiency using maximum likelihood method. He found that individual farm level technical efficiency was about 83%. His results showed that non-farm employment, education, farm experience, degree of specialization and weeding were positively related to technical efficiency and significant at 1% level, whereas, age and household size were negatively related to technical efficiency and significant at 5% and 10%, respectively. His result also revealed that there was no significant relationship between technical efficiency and extension visits and credit access.

Dolisca and Jolly (2008) employed a stochastic production frontier function to examine the socioeconomic and demographic factors that influence technical efficiency of a traditional crop (bean) and a non-traditional crop (potato) in Haiti. Their results indicate that technical efficiency for bean and potato was related to credit access and education level. Potato was technically more efficient and generated higher net returns per hectare.

Jwanya *et al.* (2014) estimated technical efficiencies and identified the determinants of technical efficiencies of rain-fed Irish potato farmers in Plateau State, Nigeria. Data were analyzed using stochastic frontier production function. The study showed that technical efficiency ranges from 2.37 to 95.6 percent with a mean technical efficiency of 74 percent. This widely varying index of technical efficiency among the rain-fed Irish potato farmers indicates great potential to achieve productivity growth through improved efficiency using existing technologies and the available resource base in the study area. The determinants of technical efficiencies were education, farming experience, potato variety and off-farm income.

Kiptoo *et al*., (2016) examined the technical efficiency of smallholder Irish potato farmers in Koibatek sub County, Kenya using data from 261 farmers. They used a Cobb-Douglas stochastic production frontier and Tobit models to estimate the farm level technical efficiency and the influencing factors respectively. The Results indicated that mean farm technical efficiency was 65.41 percent. This implies given the existing level of technology and inputs, output could be increased through better use of available resources.

Moreover, type of seed potato used and access to agricultural extension services, type of fertilizer and household size and farmer's age were statistically significant at $p<0.05$ in explaining small-holder potato farmers‟ technical efficiency. However, the study showed as there was no significant relationship between technical efficiency, membership to farmer organization and the use of credit in potato production. The study recommended reviewing existing policies that directly or indirectly address availability of clean certified seed potato, access to agricultural extension and soil analysis.

In general, different researches have conducted on efficiency of farmers in different regions using different models and different assumptions of estimation to various sets of variables, in order to measure and identify the level and sources of technical efficiency. These efficiency levels do also vary spatially and temporally. The literatures suggested that from the current level of technology and factor endowment, there is a potential to increase agricultural production by improving the demographic, institutional, and environmental factors.

2.6. Conceptual Framework of the Study

Production process involves a transformation of inputs into outputs. Inputs as well as outputs vary from one type of production to another. In potato production, inputs include area, quantity of urea fertilizer, quantity of DAP, quantity of potato seed , labour and oxen power used in oxen days which are all combined in different ratios to produce outputs. The effectiveness with which the inputs are transformed into outputs does not only depend on inputs used but also on the managerial practices that the farmer uses to combine these inputs.

Potato production in particular and crop production in general in the study area are likely to be affected by different, farm characteristics, demographic, socio- economic and institutional factors. Studies, for instance, by Kalirajan and Shand (1988) and Jema (2006) showed that efficiency of production was determined by the host of socio-economic and institutional factors.

These factors directly/indirectly affect the quality of management of the farm's operator and, therefore, are believed to bring technical efficiency difference among producer farmers. According to Bakhsh (2007), a range of factors like distinctiveness of farms, management, physical, institutional and environmental aspects could be the cause of efficiency difference in the production process of the farmers.

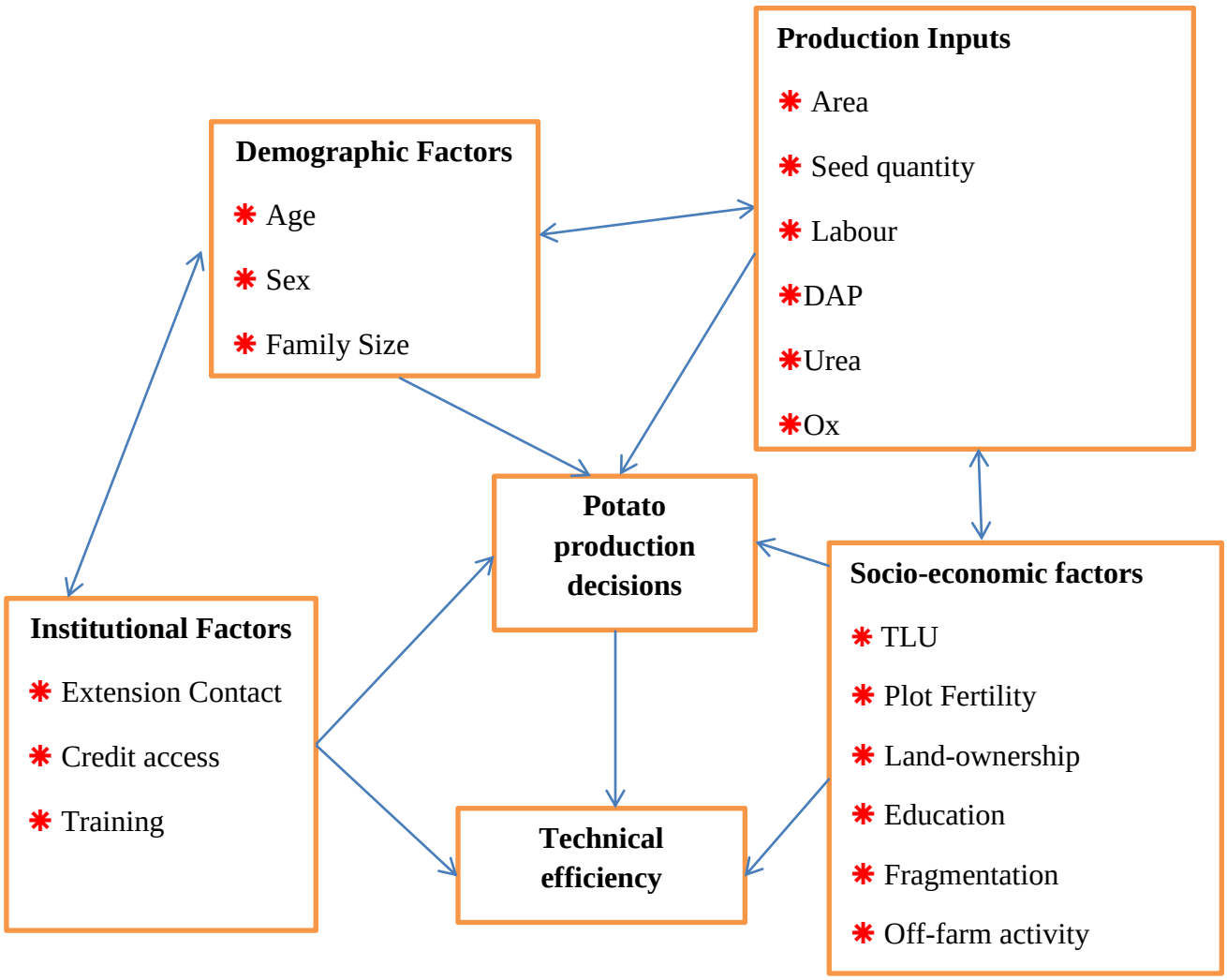

Figure 3: Conceptual framework of the study

Source: Own sketch from literature review

3. RESEARCH METHODOLOGY

In this chapter, description of the study area, sampling technique, data type and method of data collection, methods of data analysis, definition and measurement of variables hypothesized are presented.

3.1. Description of the Study Area

Dinsho District is one of the 18 Districts found in Bale Zone. It is located in South East part of the country. Dinsho District was the former part of Sinana Dinsho District. The administrative town of the District is Dinsho, located 400 km from Addis Ababa and 30 km from Robe town, which is the administrative town of Bale Zone. There are 9 rural kebeles and one-town in the District. The District is located in the coordinates of 7°10′ -7.167°N and 39°55′- 39.917°E (DDANRO, 2017).

The total population of Dinsho district was 68,675, of whom 33,202 were males and 35,473 were females; 7816 of its population were urban dwellers. The people's livelihood strategies mainly depend on mixed farming. The majority (85.98%) of the inhabitants were Muslim, while 13.65% of the population practiced Ethiopian Orthodox Christianity (DDANRO, 2017).

The altitude of the District is estimated to be in the range between 1500 meter and 3644 meter above sea level. There are two agro-climatic zones found in the District namely „Dega[1]" (95 %) and „Woinadega[2]" (5 %). This indicates that the District is the potential area for production of potato. The District gets mean annual rainfall ranging from about 3400mm to 4500mm. The mean annual temperature of the District lies between -3^0c and 24^0c (DDANRO, 2017).

Agriculture is the main stay of the woreda's economy and hence it provides almost the largest livelihood share of the population. However, it is characterized by lack of access to modern technology, low productivity, dependency on rainfall and lack of adequate irrigation practice,

etc. This and other socio-economic factors make agricultural production to be done below the potential level in this district.

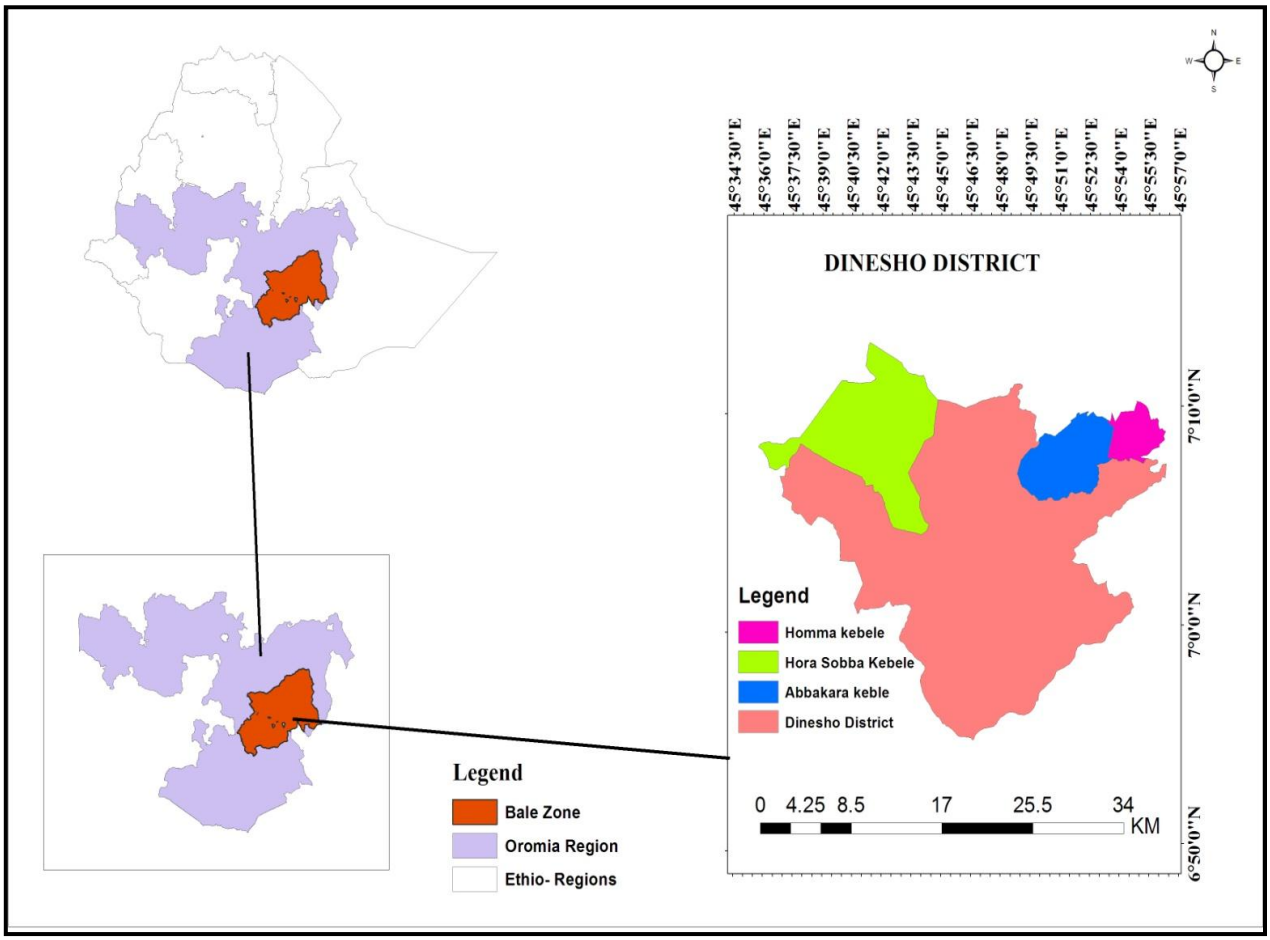

Figure 4: Map of Dinsho district

3.2. Sources and Method of Data Collection

The study was made use of both primary and secondary data sources. The primary data were collected by administering a semi-structured questionnaire to the sampled respondents by enumerators. The enumerators were trained on the content of questionnaire, method of data collection and how to approach household heads during the interview. Relevant secondary data sources were assessed from published and unpublished documents to supplement the primary data.

The major sources of data used for this study were taken from smallholder farmer's household heads. Data were collected through well prepared and pretested interview schedule that were administered to the respondents by the trained enumerators.

3.3. Sample Size and Sampling Techniques

3.3.1. Sample Size Determination

In this study, the sample size was determined based on Yamane (1967) since the population is homogenous in agro-ecology and production system. The simplified formula provided by Yamane is used to determine the required sample size at 90% confidence level and 8% level of precision. The simplified formula used to determine the sample size of the study was specified as follows.

$$n = \frac{N}{1+N(e)^2} \quad (3.1)$$

Where n is the sample size, N is the population size, and e is the level of precision. For this study 8 % of precision level was used.

Thus, following Yamane (1967), to determine the required sample size at 95% confidence level, degree of variability = 0.5 and level of precision 8%.

$$n = \frac{3150}{1+3150(0.08)2} = 148.87$$

Therefore, a total of 149 farm households were included in the sample.

3.3.2. Sampling Techniques

Since farm household heads are actually responsible for day to day farming activities, they were taken as the basic sample unit in this study. Only those households producing potato during the survey period (2016/2017) were included in the sample selection. Potato is the important crop produced in all kebeles of the District. Consequently, to select the required sample kebeles and households for this study, a two-stage sampling technique was used. In the

first stage, 3 kebeles out of nine kebeles found in Dinsho district namely Abbakara, Hoomma, and Hora soba were randomly selected. In the second stage, respondent farmers in the three sampled kebeles were selected randomly using probability proportional to size of each kebele's population.

Table 1. Distribution of sampled kebeles and households

Sampled kebeles	Total potato producing household heads	Sample
Abbakara	1095	51
Hoomma	431	21
Hora soba	1624	77
Total	3150	149

3.4. Methods of Data Analysis

In this study, descriptive statistics and econometric models were used to analyze the data collected from the sample farm households and other sources.

3.4.1. Descriptive Statistics

The data collected on socio-economic, institutional and agro-ecological characteristics of the sample households, were analyzed by using descriptive statistics Such as mean, standard deviation, frequency, percentage, etc.

3.4.2. Econometric Analysis

Before conducting the technical efficiency analysis, it is appropriate to know the production function that adequately represents the data.

3.4.2.1. Specification of the functional form

In this study, the Translog production function that is flexible and the Cobb-Douglas production function that is less flexible were estimated to select the most appropriate production function.

Then, following Battese and Coelli (1995), a stochastic frontier production function that also includes variables that may influence inefficiency in single stage estimation as used to estimate technical efficiency of potato production and its determinants in Dinsho district. This is due to the fact that one of the appealing features of SPF is that it accounts for random shocks and measurement errors. According to Gupta and Nguyen (2010), the SFA has been widely used to estimate technical efficiency of firms with basic idea lying on introduction of a composed error term consisting of a noise and an inefficiency term.

Among the possible algebraic forms, Cobb-Douglas and the translog functions have been the most popularly used models in most empirical studies of agricultural production analysis. Some researchers argue that Cobb-Douglas functional form has advantages over the other functional forms in that it provides a comparison between adequate fit of the data and computational feasibility. It is also convenient in interpreting elasticity of production and it is very prudent with respect to degrees of freedom. So nowadays, it is widely used in the frontier production function studies (Hazarika and Subramanian 1999). But it has also limitation. The disadvantage of the Cobb-Douglas functional form is that it imposes strong assumptions on the nature of the farm technology (i.e. it assumes constant elasticity over the input-output curve and unitary elasticity of factor substitution). On the other hand, there are cases where the translog model fits better to the data if the cross product effects of the independent variables have significant role in the process of maximum likelihood estimation of the parameters of the model. This functional form allows flexibility in providing approximation to any twice-differentiable function and for its ability to capture interaction among inputs (Sherestha, 1992 Cited in Mohammed, 1999). But the problem of multicollinearity is a serious problem in translog production function.

As a result, taking the advantages and disadvantages of both functional forms into consideration the appropriate functional form that better fits the data was selected after testing the null hypotheses using the generalized likelihood ratio test. The value of the Generalized log-likelihood ratio (LR) statistic to test the hypothesis that all interaction terms including the square root specification (in the translog functional form) is equal to zero ($H_0 = \beta_{ij} = 0$) was calculated as:

$$LR = -2 \{\ln ([L (cd)/ L (Tl)]\}$$

$$LR = -2 [L (cd) - L (Tl)] \quad (3.2)$$

Where: LR = Generalized log-likelihood ratio

L (cd) = Log-likelihood value of Cobb-Douglas

L (Tl) = Log-likelihood value of translog

Then this value was compared with the upper 5% point for the χ 2 distribution and decision was made based on that result.

3.4.2.2. Estimation of the empirical model

The model parameters were analyzed using the computer program; by employing a single stage estimation procedure. In using the two-stage estimation procedure of estimating efficiency level and identifying factors determining it, the efficiency index is estimated by the stochastic production function in the first stage and then regressed against a number of other farm specific and socio-economic variables in the second stage.

ML estimation procedure was used to estimate the stochastic production function model described in equation (3.4). To use ML estimation procedure, the assumptions made about the distributions of the error components u and v should be respected (Coelli, 1998). It is assumed that u_i' s are independently and identically distributed half-normal random variables with mean zero and variance σ_u^2. While v_i's are assumed to be independent and identically distributed normal random variables with mean zero and constant variance σ^2_v. ($v \sim (0, \sigma^2_v)$), independent of the u_i's. In most empirical applications the half normal distribution for the technical inefficiency effects (u_i) has been more frequently assumed.

Given a symmetric normal distribution for v_i and half normal distribution for u_i and by defining a parameter γ,

$$\sigma^2_s = \sigma_u{}^2 + \sigma^2_v \quad (3.3)$$

$\sigma_u{}^2$ = the variance parameter that denotes deviation from the frontier due to inefficiency

σ^2_v = the variance parameter that denotes deviation from the frontier due to noise

σ^2_s = the variance parameter that denotes total deviation from the frontier

$\gamma = \sigma_u{}^2 / \sigma^2_v$: which lays between zero and one and this measure the effect of technical efficiency variation of observed output. A zero value of γ indicates that the deviation from the frontier are entirely due to noise, while value of one would indicate all the deviations are due to technical inefficiency (where $\sigma^2_s = \sigma_u{}^2 + \sigma^2_v$) .

Battese and Corra (1977) showed that the log-likelihood function in terms of this parameterisation is equal to:

$$ln(L) = -\frac{N}{2}\ln\left(\frac{\pi}{2}\right) - \frac{N}{2}Log\delta_s^2 + \sum_{i=1}^{N}\ln[1-\Phi(Zi)] - \frac{1}{2\delta^2 s}\sum_{i=1}^{N}(lnYi - Xi\beta)^2 \quad (3.4)$$

Where, $Z_i = \left(\frac{lnY_i - X_i\beta}{\delta s}\right)\sqrt{\frac{\gamma}{1-\gamma}}$

Φ (.) = the distribution functions of the standard normal random variable

LnY_i = logged output level for the i^{th} farm

X_i = logarithm of the level of input for the i^{th} farm

β = Regression coefficient

γ = Discrepancy parameter as defined above

$\sigma_s{}^2$ = variance of standard error of the composed error term

N = number of observation

The ML estimates of β, $\sigma_s{}^2$ and γ were obtained by finding the maximum of the log likelihood function defined by equation (3.4). The ML estimators are consistent and asymptotically efficient (Coelli *et al*., 1998).

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

$$TE = \frac{Y_i}{\exp(x_i \beta + vi)} = \frac{\exp(x_i \beta + v_i - u_i)}{\exp(X_i \beta + v_i)} = \exp(-u_i) \quad (3.5)$$

Where, $Y_i = \exp(x_i \beta + v_i - u_i)$ is the stochastic frontier model for a sample data of n farmer,

Y_i = denotes output of potato produced by the $i^{th,}$

X_i = is (1xk) row vector with the first element equal to 1, of input quantity used by the i^{th} farmer for the production of potato,

$\beta = (\beta_0, \beta_{1\ldots} \beta_k)$ is a (k+1) column vector of unknown parameters to be estimated.

u_i = is a non-negative random variable associated with technical inefficiency of the i^{th} farmer for potato production

v_i = is random error term of the model which capture random shock of the production of potato in the i^{th} farmer and i = 1, 2, 3,….

N is number of samples in a population

u_i in this case is unobservable, so as $\exp^{(-Ui)}$. The only observed is the difference, $\varepsilon_i = v_i - u_i$. However, Coelli *et al* (1998), have indicated that the best predictor of $\exp^{(-Ui)}$ assuming half-normal distribution for u_i is:

$$E\left[\frac{\exp(-Ui)}{\varepsilon i}\right] = \frac{1-\Phi\left(\delta\forall + \frac{\gamma\varepsilon i}{\delta}\forall\right)}{1-\Phi\left(\frac{\gamma\varepsilon i}{\forall}\right)} \exp(\gamma\varepsilon i + \delta^2\forall/2) \quad (3.6)$$

Where, $\delta\forall = \sqrt{\gamma(1-\gamma)\delta^2 s}$

γ is defined above

ε_i = maximum likelihood residual ($\varepsilon_i = \ln Y_i - X_i\beta$)

Φ = Density function of standard normal random variable.

For the frontier model the null hypothesis, that there are no technical inefficiency effects in the model was conducted by testing the null and alternative hypothesis Ho: $\gamma = 0$ versus H_1: $\gamma > 0$. The hypothesis involving γ are considered due to the fact that, the Battesse and Corra (1977) parameterisation is adopted for this study and the test must be performed as a one sided test because γ cannot take negative values. As a result the One-sided Generalized Likelihood ratio test suggested by Coelli 1995 should be performed when maximum likelihood estimation is involved. This test statistic requires the estimation of the model under both the null and alternative hypotheses. Under the null hypothesis Ho: $\gamma = 0$, the model is equivalent to the traditional average response function, without the technical inefficiency effect, u_i. The test statistic is calculated as:

$$LR = -2\{Ln [L (H_0)]/Ln [L (H_1)]\}$$
$$= -2\{Ln [L (H_0)]-Ln [L (H_1)]\} \quad (3.7)$$

Where: L (H_0) = value of the likelihood function under null hypothesis;
L (H_1) = value of the likelihood function under alternative hypothesis
Ln is the natural logarithms

All the tests were carried out using generalized likelihood ratio statistics. The test statistics is defined by $\chi 2 = -2 [L(H_0) - L(H_1)]$, where $L(H_0)$ and $L(H_1)$ are the values of the likelihood function for the model under the null hypothesis, H0, and the alternative hypothesis, H_1, that are involved.

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

$$Ln(y) = f(AREA, OXEN, SEED, LABOUR, DAP, UREA; \beta_i) + \varepsilon_i$$

Where, **y** is the total output of potato obtained from the i[th] potato produced farmer in quintal.

β_i: Parameters to be estimated,

f ( ): Appropriate functional form and

ε_i : Composed error term, $\varepsilon_i = v_i - u_i$

The technical efficiency effect model (Battesse and Coelli, 1995) in which both the stochastic frontier and factors affecting inefficiency are estimated simultaneously is specified as a joint estimation of a stochastic frontier production function.

$$LnPPROD = f\{\beta_0 + \beta_1 lnAREA + \beta_2 lnUREA + \beta_3 lnDAP + \beta_4 lnOXEN + \beta_5 lnHLAB + \beta_6 lnSEED + V_i - (\delta_0 + \delta_1 AGE + \delta_2 EDU + \delta_3 FAMSZ + \delta_4 OFFOC + \delta_5 FRAG + \delta_6 TRAIN + \delta_7 FEXCON + \delta_8 ASCDT + \delta_9 LIVSTK + \delta_{10} FERT + \delta_{11} OWNL + \delta_{12} SEX + W_i)\}$$

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

3.5. Definition of Variables and Working Hypotheses

3.5.1. Variables of production function

Potato output: It is the dependent variable which refers to the physical amount of potato produced in quintals in 2016/17 production season.

AREA: This refers to the physical unit of land planted with potato measured in hectare,

OXEN: It is the amount of oxen power used by i[th] farmer during the production season which is measured in oxen days,

SEED: This refers to the amount of potato seed used in kg by the i[th] farmer

DAP: Amount of DAP chemical fertilizer used in kg by the i[th] farmer on potato farm

UREA: Amount of UREA chemical fertilizer used in kg by the i[th] farmer on potato farm

LABOUR: It is the amount of labour in man-days used for potato production

3.5.2. Variables for determinants of inefficiency

Based on previous studies and socio-economic conditions of the study area, the following factors were expected to determine technical efficiency differences of farmers.

Age: It is the age of the household head in years which is hypothesized to reflect the experience of the farmer in farming. The finding of Jwanya *et al*. (2014) showed that the experience of farmer in farming is the significant factor differentiating the technical efficiency of farmers in the study area. However, as the farmer gets older his managerial ability is expected to decrease. Therefore, in this study we hypothesized indeterminate relationship between age and efficiency.

Education (EDU): It is formal education commonly measured in years of schooling of the farmer. Technical efficiency is the ability of the farmer to get the maximum possible output at a given input. Farmers are expected to acquire the ability of better management through education. From empirical studies reviewed education is one of the most recognized factors in determining efficiency level of farmers in many area of the world.

In this study education was hypothesized to affect technical efficiency positively. The result of different researchers in different area showed the same result confirming this hypothesis (Dolisca and jolly, 2008; Bonaba-Wabbi *et al*., 2012; Jwanya *et al*,. 2014).

Land ownership (OWNL): Land ownership is one of the variables that will be considered in performance evaluation. Farmers may tend to be more efficient in managing those lands that are owned and hired than sharecropped lands. This is because farmers may tend to avert risk in sharecropped land than owned lands. In addition, they tend to give priority to their own land in all aspects. Thus, they are expected to be more efficient in managing their own and hired lands. Therefore, ownership measured in terms of dummy variable is hypothesized to determine efficiency positively. In other words, farmers who are managing either their own

land or hired land are expected to be more efficient than those farmers who are managing sharecropped land (Fekadu, 2004).

Family size (FAMSZ): This is a continuous variable representing the total number of family members in the household. Family is an important source of labor supply. Since labor is the main input in crop production, as the farmer has large family size, he/she would manage crop plots on time. Family size was found to relate positively to technical efficiency (Kinde, 2005). However, family size found to relate negatively to technical efficiency (Fekadu, 2004). Therefore the sign of this variable is expected to be positive or negative in the study area.

Frequency of extension contact (FEXCON): Frequency of extension contact is a continuous variable and medium for the diffusion of new technologies by farmers. However, some farmers visited by extension agents more frequently while others visited rarely. In the other extreme there may be farmers who never have extension contact with extension agents. It was hypothesized that there is efficiency differential among farmers who have more and less contact with extension agents. Therefore for this study, extension contact was expected to have a positive effect on efficiency (Abba, 2012).

Training (TRAIN): It is the frequency of training on potato production by different agricultural development agents. It influences the growth of agricultural by assisting the dissemination of new technologies to farmers as a way of increasing agricultural productivity. Therefore, it is important to evaluate whether training had significant impact in improving the efficiency of farmers in the production of potato in the study area.

Farmers who trained again and again are expected to be more efficient than others. Thus, training measured in number of training is hypothesized to influence efficiency level positively. In their work (Fikadu, 2004; Abdullah *et al.*, 2006) obtained the result where training given by extension workers was the significant variable influencing the efficiency level of producers in the study area.

Sex (SEX): It is dummy variable taking a value of 1 if the household head is male and 0 otherwise. Bonabana-Wabbi *et al*. (2012) came up with the conclusion that sex of the

household head is the important determinant efficiency where females were obtained more efficient than males.

However, Abebaw (2003) and Abonesh (2006) male headed household are in a better position to pull labor force than female headed ones indicating more male efficiency. Thus, in this study the sign of sex of household head on efficiency was pre-indeterminate.

Fragmentation (FRAG): Fragmented land is difficult for effective management of the crop. A farmer having more plots is expected to loss time by moving between plots. Farmers who have large numbers of plots in the same place would be expected to be more efficient than those farmers owning fragmented plots; because fragmentation of plot would make difficult to perform farming activities on time and effectively. Therefore, fragmentation measured in numbers of plots was hypothesized to affect efficiency negatively. Kinde (2005) obtained the same result.

Livestock (**TLU**): It refers to total number of livestock in TLU owned by the farm household. It is one of the resources that may determine the efficiency of farmers. Livestock supplements the production of crops in various ways. The income obtained from livestock serves to invest on crop production especially to purchase fertilizer. Livestock manure could also be used to improve soil fertility.

It is also the main sources of animal labour in crop production. Thus, it was hypothesized that livestock determine efficiency positively. In line with the hypothesis of this study, Temesgen and Ayalneh (2005) obtained the result where the size of livestock had positively influenced the technical efficiency level of farmers in the study area.

Fertility status (FERTILITY): the fertility status of the plot is defined as a dummy variable that would take a value of 1 if the plot is fertile and 0 if not. Farmers were asked to categorize their potato plot as fertile or infertile land as they will approximately know the fertility status of their plot. It was hypothesised that fertile lands are more productive than infertile plot.

Access to credit (CREDIT): This is a dummy variable that represents the use of any forms of credit associated with crop production by farmers. If the farmer has taken credit in the

production season, the variable takes a value of 1 and 0 otherwise. Kinde (2005) using SPF model found credit significantly affect technical efficiency of smallholder potato producers in Assosa district. The availability of credit for resource poor farmer is important to finance the agricultural activities. Therefore, it is hypothesized that farmers who have used credit are expected to be more efficient than others.

Off/Non-farm (OFFOC): It is a dummy variable, which have the value of one if the farmer or his economically active family members are engaged in any non-farm employment; zero otherwise. Heileselase (2005) by using SPF model found that off-farm activity affects farmers' level of performance in the production of sorghum in Reya Azebo distinct. Off-farm activities can supplement the agricultural activities in terms of providing cash income there by purchase necessary inputs timely. Therefore, participation of the household on different off-farm activity was hypothesized to affect technical efficiency of the farmers positively.

4. RESULTS AND DISCUSSION

This chapter contains two sections; descriptive statistics and econometric results. The first section presents descriptive statistics of the farm characteristics of the sample households. In the second section, econometric results of technical efficiency estimation and its determinants for potato producing households in Dinsho district are presented and discussed.

4.1. Descriptive Statistical Results

4.1.1. Demographic Characteristics

At it is explicitly indicated in Table 2, about 68.46 percent of the sample households were married and 12.75, 10.07 and 8.72percents were divorced, single and widowed, respectively.

Table 2. Marital status of the sample households

Marital status	Number of farmers	percent
Single	15	10.07
Married	102	68.46
Divorced	19	12.75
Widowed	13	8.72
Total	149	100

Source: Own survey result, 2017

The average age of the sample household heads was 40.17 years with a standard deviation of 13.09. The family size for the sample households, on average, was found to be 5.62 with a standard deviation of 3.56. With regard to religion 67.11, 24.16 and 8.72 percent's of the sample households in the study area were Muslims, Orthodox and Protestant respectively. Moreover, the average educational level of the household head, on average, was 2.43 year with a standard deviation of 2.02.

Table 3. Family size, age and educational characteristics of the sample households

Variable	Minimum	Maximum	Mean	Std. Deviation
Family size of HH	1	14	5.62	3.56
Age (year)	21	79	40.17	13.09
Education level (year)	0	12	2.43	2.02

Source: Own survey result, 2017

4.1.2. Resource Basis of the Farmers

Land: Land is, scarce and basic factors of production. According to the survey result, the average land holding of the sample households in the district was 2.52 ha with a standard deviation of 1.20. The minimum and maximum size of farm land holding was 0.20 and 4.75 hectare respectively. On the other hand, the total number of livestock ranges from 1 to 16.45TLU with a mean and standard deviation of 6.15 and 3.82, respectively. This shows that high population of livestock as well as a wide variability in terms of number livestock owned among the smallholder farmers in the study area.

Table 4. Distribution of the sample household by land size and livestock holding excluding oxen

Variable	Minimum	Maximum	Mean	Std. Deviation
Land size (hect.)	0.20	4.75	2.52	1.20
Livestock (TLU)	1	16.45	6.15	3.82

Source: Own survey result, 2017

Livestock: The study area is characterized by having livestock resources which are useful in the livelihoods of the rural communities. Livestock, especially cattle, are the most important components of the farming system in line with crop production. Among others, ox is a major input in crop production process serving as a source of draft power. Farmers in the study area use oxen to undertake different agronomic practices like preparation of land. But there are also farmers who prepare their land by hand digging for potato production. Most of these farmers do not have oxen and produce potato in small area of land basically for home consumption.

There was variability in oxen number among farmers in the study area, ranging from 0 to 9. Generally 27.52 percent of sample households in the study area have had a pair of oxen and about 8.72 percent have no oxen during the survey period.

Table 5. Distribution of oxen number among sample households

Oxen ownership Category	Sample households Number	Percent
None	13	8.72
1 oxen	3	2.01
2 oxen	41	27.52
3 oxen	15	10.07
4 oxen	19	12.75
5 and more oxen	58	38.93

Source: Own survey result, 2017

Basically in the study area cattle, small ruminants (mainly, goats) and poultry are the major types of livestock owned. To make the unit of measurement uniform, conversion factor developed by Storck *et al.,* (1991) as cited in Arega and Rashid (2005) was used to convert the herd size in to TLU.

Tenure status: The survey result showed that, about 76.51 percent of the sample farmers have owned and rented and 23.49 percent of the sample farmers have produce different crops on a shared land.

Table 6. Tenure status of sample farmers

Tenure status	N	Percent
Owned and Rented	114	76.51
Shared	35	23.49
Total	149	100

Source: Own survey result, 2017

On the subject of plot characteristics, about 56.38 percent of the sample households owned gentle slope while the remaining 43.62 percent own sloppy plots of land. Besides, 53.02 and 46.98 percent of the sample household possess fertile and infertile plot of land, respectively.

Table 7.Slope and fertility status of plot of the sample households

Nature of farm	Category	Number	Percent
Slope	Gentle	84	56.38
	Sloppy	65	43.62
Fertility	Fertile	79	53.02
	Infertile	70	46.98

Source: Own survey result, 2017

4.1.3. Input use

Obviously, farmers use different combination of inputs, such as land, fertilizer (organic and/or inorganic), seed (improved seed like Jalene and Durame, and/or local), labor and oxen in the production process. Almost all of the sample households use their own seed which were originally distributed by woreda bureau of agriculture and saved from previous harvest. Family labor, 'debo' and wenfel were the main sources of labor input for major farming activities like, weeding, digging and harvesting in the production of potato.

4.1.3.1. Off/non-farm activities

Farmers in the study area engaged themselves in various off/non-farm activities parallel with the main farming activities during the farming season. Farmers participate in non-farm activities due to shortage of land, excess family labor, and attractive income from off/ non-farm activities in the district. The income they desperately need to obtain from such off/non-farm activities will substantiate the low income that is usually obtained from their main stay, specifically farming activities. Mostly they participate in Petty trading, peddler, groceries and selling local drinks. About 77.85 percent of the sample farmers participate in various off/non-farm activities.

Table 8. Frequency and percentage of sample farmers in non-farm participation

Non-farm activity	Freq.	Percent
Not participate	33	22.15
Participate	116	77.85

Source: Own survey result, 2017

4.1.3.2. Land fragmentation

There is variation in the extent of fragmentation of land that the respondents manage. Agricultural holdings are normally not found in one compact block but in many parcels scattered across several places. The minimum and maximum numbers of plots cultivated by the sample households were one and four, respectively. The average fragment of land of the household head was 2.59 with a standard deviation of 1.17.

Table 9. Land fragmentation of the sample farmer

Variable	Minimum	Maximum	Mean	Std. Deviation
Fragment	1	4	2.59	1.17

Source: Own survey result, 2017

4.1.4. Institutional Support

Extension contact

Almost 100 percent of the sample respondents reported that they have been receiving extension services in the production season. However extension workers visit farmers on different intervals. Some farmers are being visited more frequently than others. The mean frequency of extension contact was 11.54times with a standard deviation of 4.78.

Training:

An appropriate training given to the farmers may improve productivity by enhancing their management capacity. In the study area, farmers were getting training from surrounding

research centers (like, Sinana Research Center) and other governmental (like, Madawalabu University) and nongovernmental organizations. The survey data indicated that 67.79 percent of the total respondents have been receiving training on potato production. The training includes land preparation, fertilizer application, sowing and other management practices. While the remaining 32.21 percent of the respondent did not obtain any training during the production season. In general, the mean number of training of the sample household head was 2.48 with standard deviation of 2.14.

Table 10. Distribution of Sample farmer's by frequency of extension contact and training

Variable	Mean	Std. Deviation	Minimum	Maximum
Extension contact	11.54	4.78	3	24
Training	2.48	2.14	0	6

Source: Own survey result, 2017

Credit

To the farmers in the district, formal credit is provided by Oromia credit and saving institution and Oromia cooperative bank. The survey result showed that about 73.15 percent of samples farmer had access to credit while the remaining 26.85 percent had not access to credit during the production year.

4.1.5. Production Constraints

Moisture stress is becoming a major production problem. Most of the time the area is very cold and remains cloudy throughout the production year. In addition, there is wide range of parasitic and competitive weeds causing damage on potato yield. Depending on the number of total responses, the major problems affecting potato production in the study area were ranked to be high weed infestation (19.46 percent), low fertility status of the soil due to nutrients depletion (19.46 percent), Poor land preparation (12.75 percent), low productivity of local varieties (23.49 percent) and geographical and other related problems (24.81 percent) in the area.

Table 11. Major problems of potato production in the study area

Problems of maize production	Number of respondents	Percentage
High weed infestation	29	19.46
Low fertility status of the soil	29	19.46
Poor land preparation	19	12.75
Low productivity of local varieties	35	23.49
Other	37	24.81

Source: Own survey result, 2017

4.1.6. Summary of Variables Used In the Model

The production function for this study was estimated using six input variables. To draw some picture about the distribution and level of inputs, the mean and standard deviation of input variables is discussed below as follows:

Table 12. Summary statistics of variables used to estimate the production function

Variable Description	Mean	Std. Dev.
Qpprod(kuntail)	73.76	57.09
Area(ha)	0.41	0.30
Seedqt(kg)	1235.24	1032.02
Labour(MDs)	28.29	14.55
DAP(kg)	31.74	25.55
Urea(kg)	50.16	29.09
Ox(ODs)	9.13	5.50

Source: Own survey result, 2017

On average farmers in the study area produced 73.76 quintals of potato. The average land allocated for potato production by the sample households during the survey period was 0.41 ha. The other very important variable is seed. The average amount of seed sample households' used was 1235.24 Kg. Like other inputs human and animal labor inputs were also decisive, given a traditional farming system in the study area. As the survey data indicates sample

households, on average, used 28.74 man- days and about 9.13 oxen days for the production of potato during 2016/17 production season. In the study area farmers use Urea and DAP for potato production.On average farmers used 50.16 Kg of Urea and 31.74 Kg of DAP.

A total of 12 variables were hypothesized to affect efficiency of potato producers, out of which five of them were dummy variables and the rest seven are continuous variables. Table 13 below portrays summary of these variables.

Table 13. Summary of variables used in the model

Variable	Mean	Std. Dev.	Percentage of the mean with Dummy=1	Percentage of the mean with Dummy=0
Age	40.17	13.08	-	-
Education	2.43	2.02	-	-
Family size	5.62	3.56	-	-
Livestock	6.15	3.82	-	-
Frequency of extension service	11.54	4.78	-	-
Training	2.48	2.14	-	-
Fragmentation of land	2.59	1.17	-	-
Sex	-	-	83.89	16.11
Land-ownership (Tenure)	-	-	76.51	23.49
Access to credit	-	-	73.15	26.85
Non-farm income	-	-	77.85	22.15
Fertility status	-	-	53.02	46.98

Source: Own survey result, 2017

4.2. Econometric Results

This section presents the econometric results of the study. The results of production functions, efficiency scores and determinants of efficiency are presented and discussed successively.

In this study, a cross-sectional data from a sample of 149 farmers was used for estimation of technical efficiency of potato producer households and to identify sources of technical efficiency variations among them in the study area. Six input variables namely area, seed, DAP, Urea, human labor and oxen power were used in the analysis. In addition to this, there were twelve inefficiency variables namely sex of household head, age of household head, family size, education level, fragmentation, training, livestock holding, land ownership, frequency of extension contact, access to credit, fertility status of land and off/non-farm activities considered for estimating technical efficiency.

4.2.1. Test of Hypothesis

One attractive feature of SPF method is that it is possible to test various hypotheses using maximum likelihood ratio test, which were not possible in non-parametric models. Therefore, the first hypothesis tested was whether Cobb-Douglas production function fits the data at hand for potato production in the study area or not. The functional form that can better fit to the data at hand was selected by testing the null-hypothesis that the coefficients of all interaction terms and square specifications in the translog functional forms are equal to zero ($H0= \beta ij= 0$). The test was made based on the value of likelihood ratio (LR) statistics which can be computed from the log likelihood values of both the Cobb-Douglas and Translog functional forms. Then, the value was compared with the upper 5% critical value of the $\chi 2$ at the degree of freedom equals to the difference between the numbers of explanatory variables used in both functional forms (in this case df =21). In other words, the degree of freedom is the number of interaction terms and square specifications in the translog case restricted to be zero in estimating the Cobb-Douglas functional form.

The log likelihood functional values of both Cobb-Douglas and Translog production functions were -48.78 and -35.07 respectively. The LR value computed therefore was 27.42 and this value is lower than the upper 5% critical value of the $\chi 2$ which is 32.67 at the degrees of freedom equal to 21. As a result the null hypothesis that all coefficients of the interaction terms in Translog specification are equal to zero was not rejected. This implies that the Cobb-Douglas functional form adequately represents the data under consideration. Hence, the

Cobb-Douglas functional form was used to estimate the technical efficiency of the farmers in the study area.

The second hypothesis was testing for the existence of the inefficiency component of the total error term of the stochastic production function. In other words, we have to decide whether the average production function (without considering the non-negative random error term) best fits the data. Computing the likelihood ratio (LR) from the log likelihood functions of both the average response function and the stochastic production function, we can perform the test for the null hypothesis that the inefficiency component of the total error term of the stochastic frontier specification equals to zero ($\gamma = 0$) against the alternative hypothesis that inefficiency component is greater than zero ($\gamma > 0$). If the null hypothesis is accepted (i.e. one-sided error term is equal to zero) then the stochastic model is identical to the average response function indicating that there is no inefficiency problems within potato producing farmers.

The likelihood ratio statistic computed (using one-sided generalized likelihood ratio test of $\gamma = 0$) from the values of log likelihood functions under both the average response function and full frontier function given the specification of the Cobb-Douglas production function was 188.26. The value is much higher than the $\chi 2$ critical value for the upper 5% which is 3.84 at one degree of freedom. The greater computed LR value reveals the existence of inefficiency or one-sided error component in the model. Hence, the hypothesis that potato producers in the study area are technically efficient is strongly rejected. As a result, the production behavior of potato producers in the study area can better be represented by the stochastic production function than the average response function.

The last hypothesis to be tested was that the null hypothesis that the explanatory variables associated with technical inefficiency effects are all zero, (H_0: $u_{i=}\delta_0 = \delta_1 = \delta_2 - - - \delta_{12} = 0$). To test this hypothesis likewise, λ (The inefficiency effect) was calculated using the value of the log-likelihood function under the stochastic production frontier model (a model without explanatory variables of inefficiency effects, H_0) and the full frontier model (a model with variables that are presumed to determine inefficiency of each farmer, H_1).

The calculated value of $\lambda = -2 (-48.78- (-19.63)) = 58.30$ is greater than $\chi 2$ critical value of 21.03 at 12 degrees of freedom This implying that the null hypothesis that variables in the inefficiency effect in the stochastic frontier model are simultaneously equal to zero was rejected at the upper 5% significance level. Therefore, the explanatory variables associated with inefficiency effects model are simultaneously different from zero. Hence, these variables simultaneously explain the difference in inefficiency among farmers.

Table 14. Summary of generalized likelihood ratio test of hypotheses for parameters of SPF

Null hyphotesis	Degre of freedom	LR	$\chi 2$ Value	Decision
H_0:β_7=β_8…β_{27}=0	21	27.42	32.67	Accepted
H_0: γ=0	1	188.26	3.84	Rejected
H_0 : λ=δ_1=…δ_{12}= 0	12	58.30	21.03	Rejected

Source: Own survey result, 2017

4.2.2. Parameter Estimates of the SPF Model

As indicated in the hypothesis test, the specified CobbDouglas functional form of the stochastic frontier model with half-normal distributional assumption of the error terms is considered to estimate the model or parameters of the model. The Parameters were estimated simultaneously with those involved in the model for the inefficiency effects. The estimation is carried out using FRONTIER version 4.1 computer programs in a single stage estimation procedure which has an advantage of consistency over the two stage estimation approach (Coelli and Battese, 1996).

The coefficients of input variables in the Cobb-Douglas production function are interpreted as elasticity of production. The model result revealed that seed quantity, area allocated for potato production and quantity of urea fertilizer applied affected output of potato significantly. The positive elasticity of inputs implies any intervention that improves the use of that input would give significant improvement in potato output while negative coefficient of input lower output of potato.

Table 15. Maximum-likelihood estimates of the Cobb- Douglas SPF with inefficiency model

Variable	Coefficients	Standard Error
Constant	0.828	0.614
Lnurea	0.189***	0.062
Lndap	0.009	0.030
Lnseedqt	0.478***	0.078
Lnlabor	0. 061	0.084
Lnarea	0.325***	0.092
LnOx	0.047	0.092
Sigma-squared (δ^2)	0.22***	0.045
Lambda (λ)	1.78***	0.097
Gamma (γ)	0.76***	
Log-likelihood function	-48.78	
N	149	

Source: Own survey result ,2017

Note: **** indicate significance of the estimates at 1 % level.

The result of the model showed that among six input variables only the parameter for area, Urea chemical fertilizer and seed quantity were found to be significant and had positive coefficients. The positive coefficients of these variable inputs imply that an increase in quantities and improving the qualities of these inputs would result in an increase in output of potato.

The coefficients of inputs indicate that on average a 1% increase in area, urea, and seed increases the output of potato by 0.189%, 0.325%, and 0.478%, respectively.

The parameter estimate for oxen power used, DAP chemical fertilizer and labour turned out to be insignificant (Table 15). The insignificance of the estimated coefficients for oxen, DAP and labour imply that more use of these inputs has no significant effect on potato production in the study area.

Coefficient parameters are also summed up to know about the returns to scale. The value of 0.98 scale coefficient in this case could indicate that an increase in all these inputs by 1% may lead to an increase in production of potato by 0.98%. This is in stage two of production function where the output will increase at less than the unit increase in inputs. The maximum-likelihood parameter estimates of the model besides telling the relative importance of individual inputs and their aggregate significance in the production process they are also used to predict the level of individual farmer's technical efficiency.

The diagnostic statistics of inefficiency component, sigma squared (σ^2) was 0.22 and was significantly different from zero and significant at 1% level of significance. The significant value of sigma square indicates the goodness of fit and correctness of the specified assumption of the composite error terms distribution. In addition, the estimate for the variance parameter gamma value was 0.76 and was statistically significant at one percent. This result suggests that about 76% of the deviation from the production frontier is due to inefficiency of farmers. Or it indicates as most important part of the residual variation is due to the inefficiency effect u_i. Whereas, only 24% of the deviation could have resulted from random error, that is due factors outside the control of the farmer.

4.2.3. Technical Efficiency Scores

One of the main objectives of this study was to measure the technical efficiency levels of potato producing farmers in Dinsho district. Given the functional form used, estimation procedure implemented, distributional assumption made about the inefficient parameter, U_i, the mean technical efficiency was estimated to be 74% (Table 16). This value indicates that farmers are not technically efficient in producing potato in the study area.

The result has hinted that on average farmers can increase output by 26% given the existing level of inputs. Or it is an indication to the farmers that there is a possibility of minimizing input level by 26% without affecting the existing level of output. The estimated levels of efficiency differ substantially among farmers, ranging from 0.23 to 0.98.

Table 16. Technical efficiency of sample farmers

Description	TE estimates
Mean	0.74
Minimum	0.23
Maximum	0.98
Standard deviation	0.19

Source: Own survey result, 2017

According to Stevenson (1980), grouping efficiency levels of the farmers can be done based on the relative performance of each sample farmer to the mean performance level. In this case, sample farmers were categorized into three groups based on the mean efficiency and the corresponding standard deviations. In this respect, farmers are considered as less efficient, if they were operating at less than the mean minus standard deviation, more efficient if operating at more than the mean plus standard deviation and of moderately efficient otherwise. The three different groups and percentage of farmers in each group are indicated in Table 17.

Table 17. Frequency distribution of sample farmers by efficiency groups

Efficiency Groups	Scores	Frequency	Percent
Less efficient	$\leq$0.55	24	16.11
Moderately efficient	0.56-0.93	109	73.15
More efficient	$\geq$ 0.94	16	10.74
Total	149	149	100

Source: Own survey result, 2017

Table 17 implies that the majority (67.78 percent) of the farmers operate within the moderately efficient group. This stipulates that there is technical inefficiency in resource use while reflecting that there is considerable scope for rising potato production through improving farmers' technical management abilities.

4.2.4. Actual and Potential Levels of Output

The awareness of the individual farmer efficiency level and their corresponding actual output enables to determine how much yield is lost because of efficiency problems in the current production practice. Similarly, it is possible to find out the potential level of production that could have been produced by the farmer had there been efficient use of the existing resources. From the relationship of technical efficiency in a given period of time as the ratio of the actual output (Y_i: exp ($x_i\beta + v_i - u_i$)) to the potential output (Y_i*: exp ($x_i\beta + v_i$)), the potential potato production of each individual farmer is calculated as follows:

$$TE_i = Y_i/Y_i^* = \exp(-u_i) \text{ which gives } Y_i^* = Y_i/TE_i$$

By using the values of the actual output obtained and the estimated technical efficiency indices, the potential output was estimated for each household in potato production per hectare. The mean value of the actual and the potential output were 73.79 qt/ha and 92.39 qt/ha, respectively (Table 18). The results, in general display existence of technical inefficiency in the study area. Therefore, if farmers use the existing agricultural inputs at optimal proportion level, a maximum of 242 qt of potato can be obtained per hectare.

Table 18. The potential and the actual yield levels of the respondent farmers

Statistics	Actual yield/ha	Potential yield/ha
Minimum	4	9
Maximum	225	242
Mean	73.79	92.39
Std. Deviation	57.06	60.75

Source: Own survey result, 2017

4.2.5. Determinants of Technical efficiency

After having the information about the existence of technical efficiency variation and measuring its magnitude, identification of the major factors which cause differences in efficiency level among farmers is one of the objectives of the study.

The determinants of technical efficiency in a given period vary considerably depending on the socio-economic conditions of the study area particularly pertaining to managerial characteristics and other related factors.

The coefficients of inefficiency variables included in the model were estimated simultaneously by the MLE procedure using the estimated level of TE as dependent variable. Since the dependent variable of the inefficiency function represents the mode of inefficiency, a negative sign on an estimated parameter implies that the associated variable had a positive effect on efficiency, and a positive sign indicates that the reverse is true.

The parameters of the various hypothesized variables in the technical inefficiency effect model that are expected to determine efficiency differences among farmers are estimated through MLE method using a one-stage estimation procedure.

Table 19 shows the result of the technical inefficiency model estimates. From twelve inefficiency variables hypothesized to determine efficiency, only five variables namely, landownership, fertility status, education level, frequency of extension contact, and land fragmentation have appeared with expected signs and statically significant.

The negative and significant coefficients of landownership, fertility status of the land, frequency of extension contact, and education level of the household head shows the positive effect of these variables on efficiency. That is, as these variables increase the efficiency of the farmer also increases. On the other hand, the positive and significant coefficient of fragmentation indicates that this variable affect efficiency negatively. MLE result and the interpretation of the significant variables are presented as follows.

Table 19. Maximum likelihood estimates of the inefficiency effect model

Variables	Coefficient	Standard-error	t-value
Constant	0.102	0.976	0.10
Sex	0.206	0.440	0.47
Age	-0.004	0.015	-0.28
Tenure status	-0.868	0.362	-2.40**
Family size	0.024	0.050	0.47
Fertility status	-1.013	0.334	-3.03***
Training	0.089	0.077	1.16
Education	-0.202	0.110	-1.84*
TLU	-0.0002	0.053	-0.00
Frequency of extension contact	-0.224	0.064	-3.49***
Access to credit	-0.035	0.394	-0.09
Fragmentation of land	0.595	0.147	4.05***
Non-farm income	0.126	0.376	0.34
Sigma-Squared ($\boldsymbol{\delta}^2$)	0.22***	0.045	
lambda (λ)	1.78***	0.097	
Gamma ($\boldsymbol{\gamma}$)	0.76		
Log-Likelihood Function	-48.78		
Mean efficiency	0.74		

Source: Own survey result, 2017

Tenure status: It is one of the variable that was considered in performance evaluation. Farmers may tend to be more efficient in managing those lands that are owned and hired than sharecropped lands. This is due to farmers give priority to their land as they would acquire the whole output that would be obtained from their own or hired lands. The result shows tenure status found to determine the efficiency level of farmers in producing potato positively and significantly.

The finding in Table 20 reveals that the mean efficiency levels of those farmers who produce potato on sharecropped land are less efficient than the other farmers.

Table 20. Land ownership and mean level of technical efficiency

Ownerships	N	Mean TE	t-value
Owned and hired	114	0.77	3.33***
Sharecropper	35	0.65	

Source: Own survey result, 2017

Sharecroppers have a mean technical efficiency level of 0.65, which is less than 0.77 in the production of potato. There is high and significant difference between sharecroppers and own and hired land producer in the level of efficiency. The t-test also proves that we can reject the null hypothesis at one percent that these two groups are equal. The result is consistent with the result found by Fekadu (2004).

Fertility status of the land: As expected, the coefficient of fertility status for technical efficiency is positive and statistically significant at 1% significance level. This implies that farmers having fertile land were more efficient than those who have less fertile land. This may be associated with those fertile lands require less commercial fertilizer application which leads to reduction in efficiency of farmers. Therefore, any activities and management practice for the improvement and maintenances of fertility of the land will have positive impact in raising efficiency of the farmers in the study area. The result is similar to the findings of Wajana (2016) and Awol (2014).

As Table 21 shows that, the mean technical efficiency of farmers producing potato on fertile land was 0.77 and those farmers producing on infertile land was 0.70. This shows that farmers operating on fertile land are 7% more efficient than those farmers operating on infertile land. The t-test also proves that we can reject the null hypothesis at 5 percent that these two groups are equal.

Table 21. Mean technical efficiency between fertile and infertile land operators

Fertility	N	Mean TE	t-value
Fertile land	79	0.77	2.095**
Infertile land	70	0.70	

Note: ** indicates significant at 5% level
Source: Own survey result, 2017

Education: Education is important to increase the managerial capacity of the farmer's in decision making. In this study, education measured in years of schooling is hypothesized to determine technical efficiency positively. As the result of technical inefficiency model in Table 19 indicates, education was found to be a negative sign coefficient and significant at 10% significant level in the inefficiency model result. This indicates that educated farmers are technically more efficient than illiterate ones. This could be because; farmers who followed formal education have the ability to use information from various sources and can apply the new information and improved technologies on their farm which result in increase of their outputs.

The simple correlation coefficient of technical efficiency and education is 0.36. This indicates the presence of positive linear relation between efficiency levels and education. In order to see how education affects efficiency, farmers were grouped into three categories depending on the class year of the household. The mean comparison among these groups was summarized as follows.

Table 22. Relationship between technical efficiency level and education

Education (Class year)	Number	Mean TE
Illiterate (0 class)	26	0.66
1 - 3	97	0.73
>=4	26	0.85

Source: Own survey result, 2017

As indicated in the above Table, the mean technical efficiency of the illiterate farmers was 0.66 whereas the mean technical efficiency of the farmers from grade one up to three, and grade four and above was found to be 0.73 and 0.85, respectively. This reveals that as the class year of the household increases the level of technical efficiency of the farmers under consideration also increases. This result was in line with the findings of Jwanya *et al*., 2014), Hailemaraim (2015) and Alemitu (2017).

Frequency of extension contact: The extension service given by the development agents to the farmers can increase the overall performance of the farmers significantly. It was measured as the number of contact days of the sample farmer spent with extension workers during the production season. It was hypothesized that those farmers with frequent extension contact are more efficient than those with lesser extension contact. As expected frequency of extension contact has significant and positive effect on technical efficiency at 1% probability level. This implies that a household who contacted frequently with extension agent during the cropping period were technically more efficient than those household with less contacted with extension agents.

This is due to the fact that extension services offer guidance to the farmers related to the use of various resources such as fertilizer and provide consultancy services when farmers face various problems related to the production process. The frequent contact facilitates the flow of new ideas between the extension agent and the farmer, thereby giving an opportunity for improvement in farm efficiency.

The simple correlation coefficient of technical efficiency and frequency of extension contact is 0.49. This shows the presence of positive linear relation between technical efficiency of the farmers and frequency of extension contact. In order to see the mean difference efficiency level, farmers in the survey year were grouped into two categories depending on the frequency of extension agent contact with the household. The mean comparison among these groups was summarized as follows.

Table 23. Relationship between frequencies of extension contact (visit) and mean technical

Extension contact	Number	Mean TE
<=10 days	86	0.68
>10 days	63	0.83

Source: Own survey result, 2017

As shown in Table 23 above, the mean technical efficiency of the farmers who got the extension service up to ten days was 0.68 whereas the mean technical efficiency of the farmers who got the extension service more than ten days in the production season was 0.83. This tells

that as frequency of extension agent contacted with household in the production season increases, the level of technical efficiency of the farmers under consideration also increases. This result was in line with the findings of most studies reviewed including those of Musa (2013), Hailemaraim (2015) and Alemitu (2017).

Fragmentation: It represents the number of pieces of land on which the farmer grows potato. It was hypothesized that a farmer with more fragmented land measured by the number of plots, is less efficient than a farmer with more amalgamated area. The positive and significant value of the coefficient of fragmentation in Table 19 is in line with the previous expectation. This may be because of as the number of plots operated by the farmer increases; it could be difficult for the farmers to manage these plots. Thus farmers that have large number of plots may waste time in moving between plots.

The mean comparison in Table 24 indicates that farmers operating on large number of plots, greater than 3 scored an average efficiency level of 0.64 while farmers who operate on less and equal to 3 plots scored an average efficiency of 0.78.

Table 24. Mean technical efficiency and number of plots

No. of Plots	N	Mean TE
< =3	106	0.78
> 3	43	0.64

Source: Own Survey data, 2017

It has an important policy implication in that ways to merge the number of plots would improve efficiency levels of farmers. This result is in line with the findings of Fekadu (2004) and Kinde (2005)

5. SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. Summary and Conclusion

Agricultural output or productivity can be increased either through introduction of modern technologies or by improving the efficiency of inputs at the existing technology. Alternatively, productivity growth may attribute to either technological progress or efficiency improvement. Improving technical efficiency of the farmer plays a great role in increasing productivity given the current state of technology in Ethiopia.

This study was designed to evaluate the technical efficiency in potato production of small holder farmers in Dinsho district, Oromia national regional state, Ethiopia. The main objectives of this study were to estimate the existing level of technical efficiency in the production of potato and to identify the determinants of technical efficiency of potato production in the study area.

Data was collected from both primary and secondary sources. The primary data was collected from the sample farmers, using a structured questionnaire whereas; secondary data was collected from published and unpublished documents from the district agricultural office. In this study two stage sampling techniques was used to select a sample of 149 potato producer households.

Data analysis was carried out using descriptive statistics and econometric models. Stochastic frontier model with inefficiency effects was used for analyzing cross sectional data obtained from 149 sample farmers in 2016/17 production season. The stochastic frontier production function of Cobb-Douglas functional form was found to best fit the data, and was applied to estimate the level of individual technical efficiency and used to estimate the production functions. The estimated stochastic production frontier model indicated that amount of Urea fertilizer, area covered by potato and quantity of seed used were significant determinates of production level of potato in the study area . The positive coefficient of these parameters indicated that increased used of these inputs until the optimal level will increase the production level of potato output up to its optimal level.

Stochastic frontier production function specification was found better represent the data set of potato production than the traditional average production function . Hence, the parameters were estimated using the maximum likelihood estimation procedure of the stochastic frontier production function, taking the inefficiency component of the total error term into account. The value of the discrepancy , γ, calculated from the maximum likelihood estimation of the frontier was 0.76. This indicates that about 76% of the variability in output from potato producer sample households was attributed to technical inefficiency effect while the remaining 24% variation in output was due to the effect of random noise.

The test result indicates that there was a significant proportion of variation in the stochastic frontier production function due to technical inefficiency implying that there is an opportunity for improvement in potato production by improving the inefficiency of farmers with the existing technology and resource. The single stage estimation analysis indicated that households could increase potato production by 26% without increasing inputs if they were technically efficient.

The generalized likelihood – ratio test revealed that variables considered in the inefficiency effects model simultaneously explained the existing technical efficiency differences among farmers. Hence, identifying factors that determine the technical inefficiency level of farmers in potato production help to improve the technical efficiency of farmers. The estimated SPF model together with the inefficiency parameters show that education level, fertility of land, land-ownership and number of extension contact significantly and negatively influenced the inefficiency of farmers, which illustrates that these variables affected technical efficiency of farmers positively. On the other hand, fragmentation of the plot positively and significantly affected technical inefficiency, which shows that this variable affected technical efficiency of farmers negatively. These factors have important policy implications in that to mitigate the existing level of inefficiency of farmers in the production of potato development programs should act upon these variables.

5.2. Recommendations

The result of the analysis revealed that potato producers in the study area are not operating at full technical efficiency levels and the result indicated various opportunities for potato producers to increase output at existing levels of inputs without compromising yield with present technologies available at the hand of producers. Based on the results of the study the following possible policy recommendations are drawn.

1. The parameter estimates of the SPF model showed that area, use of urea fertilizer in kg and potato seed used are the determinant input variables in the production of potato in the study area. This implies that, technical efficiency of the farmers can be increased through better allocation of these resources. This can be possible by providing new variety potato seed and urea fertilizer to the farmers on time. Expanding area allocated for potato production which make possible for adoption of new technology is also significant factor in the district. Thus, government or other concerned bodies in the developmental activities working with the view to boost production efficiency of the farmers in the study area should work on improving productivity of farmers by giving especial emphasis for significant factors of production.

2. Education was important determining factor that has positive and significant affect to technical efficiency of potato production. This indicates that education is fundamental in improving the technical efficiency and thereby the performance of farmers. This is because; educated farmers have access to information and better communication media that helps them to use modern agricultural potato production technologies efficiently. Therefore, it is recommended that the regional government need to have a prime responsibility to keep on the establishment of education, both formal and non-formal, in these areas, so that farmers can use the available inputs more efficiently under the existing technology.

3. Fertility of potato farm affected technical efficiency of farmers positively and significantly. Fertile and well-managed soils are of fundamental importance for well growth of potato plant. Policies that support proven land management practices will allow communities to better prevent land degradation, restore degraded lands and reduce the need for further conversion of natural forests and grasslands. Therefore, development programs should give due emphasis to improve and maintain the fertility of land through awareness creation and introduction of

technologies that improve and maintains fertility so that the efficiency of the farmers increases.

4. Land ownership measured in terms of dummy variable affected technical efficiency significantly and positively. An interesting finding from this study reveals that sharecropped potato producers tend to have lower output of potato than farmers who produce on their own and hired land. The analysis shows that there is about 12 percent mean TE difference between own and sharecropped potato producers. This may be due to farmers are expected to give priority to their land as they would acquire the whole output that would be obtained from their own or hired lands. These because outputs obtained from sharecropped lands are shared between the owner and the operator farmer. Farmers are expected to be rational in that they will allocate their time and input resources in such a way that they would get the maximum output. As a result, there should be measures taken which involves the changing of laws, regulations or customs regarding to land ownership. So by improving land policy that would increase the ownership right of farmers on land it would be possible to increase the efficiency of farmers in the study area.

5. The result of this study showed that extension contact had a positive effect with technical efficiency. This indicates as farmers who have more access to extension service were more efficient than farmers with relatively less access to extension service. This reveals that Policies and strategies that improve extension services could help to raise the efficiency of potato production. Therefore, government should design and implement policy and strategy to increase extension contact specially in the area that help farmers in getting up to date information about new technology, application of chemical fertilizer, the introducing new productive potato seed varieties etc. that has direct influence to improve farm level efficiency of potato production.

6. A fragmentation of land is significantly and negatively affects technical efficiency. Farmers that operated on many number of plots are less efficient than others. This is due to plots in the area are fragmented and very far from each other, farmers would make difficult to perform farming activities on time and effectively. Increased land fragmentation leads to inefficiency by creating shortage of family labor, costing time and other resources that should have been

available at the same time. Therefore, government and all the concerned bodies (including farmers themselves) need to give strong emphasis for consolidated land holding policy which increases the efficiency of the farmers.

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7. APPENDICES

Appendix Table 1. Conversion Factors used to compute Man- Days (MDs)

Age group (years)	Male	Female
<10	0	0
11-13	0.2	0.2
14-16	0.5	0.4
17-50	1.0	0.8
>50	0.7	0.5

Source: Strock *et al*. (1991)

Appendix Table 2. Conversion factors used to estimate Tropical Livestock Unit (TLU)

Animal category	TLU
Calf	0.25
Donkey (young)	0.35
Heifer	0.75
Sheep and goat (adult)	0.13
Sheep and goat (young)	0.06
Cow and ox	1.0
Donkey (adult)	0.70
Horse	1.10
Chicken	0.013

Source: Strock, *et al*. (1991)

Appendix Table 3. MLE of Translog Production Function

Variable	Coefficients	Standard Error
Constant	-2.560	8.563
lnArea	2.672	2.403
Lndap	-1.325	1.372
Lnseedqt	1.735	2.751
Lnurea	1.198	2.004
Lnlabour	1.50	2.881
Lnox	-1.404	3.214
lnArea2	0.336*	0.196
lnlabour2	0.539**	0.235
lnseedqt2	-0.195	0.174
lndap2	0.019	0.027
lnurea2	-0.009	0.127
lnox2	0.161	0.308
lnArea*lndap	-0.180	0.217
lnArea*lnurea	0.054	0.301
lnArea*lnlabour	0.535	0.441
lnArea*lnseedqt	-0.343	0.444
lnArea*lnox	-0.253	0.504
Lndap*lnurea	0.085	0.092
Lndap*lnlabour	-0.082	0.112
Lndap*lnseedqt	0.153	0.159
Lndap*lnox	-0.015	0.129
Lnurea*lnlabour	-0.339*	0.198
Lnurea*lnseedqt	0.078	0.242
Lnurea*lnox	-0.312	0.279
Lnlabour*lnseedqt	-0.267	0.349
Lnlabour*lnox	-0.512	0.387
Lnseedqt*lnox	0.488	0.362
Sigma-Squared ($\boldsymbol{\delta}^2$)	0.22***	0.06
lambda (λ)	2.42***	0.15
Gamma ($\boldsymbol{\gamma}$)	0.85***	0.022
Log-Likelihood Function	-35.07	
N	149	

Source: Own survey result, 2017

Appendix Table 4. Estimated level of individual household technical efficiency

HH ID.No	TE	HH ID.No	TE	HH ID.No	TE	HH ID.No	TE	HH ID.No	TE
1	0.36	31	0.49	61	0.39	91	0.94	121	0.82
2	0.74	32	0.23	62	0.31	92	0.84	122	0.95
3	0.76	32	0.91	63	0.89	93	0.97	123	0.94
4	0.97	34	0.78	64	0.79	94	0.79	124	0.90
5	0.69	35	0.95	65	0.43	95	0.90	125	0.55
6	0.75	36	0.66	66	0.84	96	0.79	126	0.75
7	0.71	37	0.59	67	0.79	97	0.55	127	0.79
8	0.82	38	0.89	68	0.85	98	0.95	128	0.97
9	0.89	39	0.76	69	0.67	99	0.78	129	0.78
10	0.98	40	0.91	70	0.80	100	0.82	130	0.82
11	0.61	41	0.79	71	0.46	101	0.69	131	0.53
12	0.26	42	0.79	72	0.88	102	0.92	132	0.39
13	0.69	43	0.88	73	0.61	103	0.82	133	0.94
14	0.92	44	0.61	74	0.96	104	0.91	134	0.84
15	0.88	45	0.68	75	0.73	105	0.87	135	0.55
16	0.94	46	0.93	76	0.46	106	0.86	136	0.87
17	0.69	47	0.63	77	0.89	107	0.75	137	0.93
18	0.95	48	0.34	78	0.80	108	0.78	138	0.95
19	0.23	49	0.91	79	0.72	109	0.87	139	0.73
20	0.74	50	0.47	80	0.77	110	0.90	140	0.66
21	0.78	51	0.80	81	0.56	111	0.65	141	0.81
22	0.91	52	0.60	82	0.73	112	0.70	142	0.63
23	0.89	53	0.27	83	0.78	113	0.84	143	0.44
24	0.68	54	0.40	84	0.90	114	0.83	144	0.57
25	0.94	55	0.95	85	0.89	115	0.96	145	0.93
26	0.76	56	0.39	86	0.85	116	0.96	146	0.39
27	0.73	57	0.88	87	0.84	117	0.63	147	0.95
28	0.96	58	0.44	88	0.90	118	0.96	148	0.42
29	0.43	59	0.46	89	0.86	119	0.33	149	0.64
30	0.70	60	0.70	90	0.58	120	0.74		

Source: Own survey result, 2017

Appendix 5. Questionnaires used for the study

Part I. General Information

1. Name of household head_____ Age _____

2. Name of Kebele _____

II. Personal Information of the Household Head and the Family

1. General description about the farm households

1.1. Local name of the field/ _____
1.2. Name of the household's head _____
1.3. Sex: 1. Male 2. Female
1.4 Age: _____
1.5 Education level: 1. Illiterate 2. Read & Write 3. Formal education (Grade___)
1.6. Marital Status: 1. Single 2. Married 3. Divorced 4. Widow
1.7. Number of Family Members (including the head): Male_____ Female _____Total ___
1.8. Religion: 1. Orthodox _____ 2. Muslin _____ 3. Protestant _____ 4. Other specify _____

2. General description of the plot

2.1. Land ownership 1. Owned 2. Rented 3. Shared 4. None

2.2. Plot distance from the residence in km (in walking minutes)?
Plot 1_____ Plot 2_____ Plot 3_____ Plot 4_____
2.3. Soil type 1. Red 2. Black 3. Brown 4. Other specify_____
2.4. Slope of the plot 1. Sloppy 2. Gentle
2.5. Fertility status 1. Fertile 2. Not /less fertile
2.6. Land use pattern: Total Area of land _____ (ha) Homestead land_____ (ha)
Cultivated land_____ (ha) Fallow land_____ (ha)
Grazing land_____ (ha) other land_____ (ha)

3. Farming practices

3.1. Which season(s) is the most important for your agricultural activities?
1. Meher 2. Belg 3. Belg and Meher 4. All year

3.2. Land preparation 1. Good 2. Medium 3. Bad

3.3. Vegetative growth 1. Good 2. Medium 3. Bad
3.4. Weed infestation 1. High 2. Medium 3. Low
3.5. Dominant weeds 1. Grass weeds 2. Broad leaves 3. Mixed 4. Others_____

3.6. Are there soil conservation structures built on the land? 1. Yes 2. No

3.7. If the answer of the above question if yes, which type of soil conservation structures used?

1. Soil bund 2. Terracing 3. Check dam 4. Agro-forestry Practices 5. Others _____

4. Livestock, land and farm implements ownership

4.1. Livestock ownership in number

No	Type of animal	No owned	TLU
2	Cow		
3	Heifer		
4	Calves		
5	Donkey		
6	Camel		
7	Sheep young		
8	Sheep adult		
9	Goat young		
10	Goat adult		
11	Chicken		

4.2. **Land ownership**

Sr. No	Owned	Rented	Shared	Total
1				
2				
3				

4.3. Do you have farmland, which is not owned? 1. Yes 2. No

4.4. If yes, if the land is rented, how much did you pay? _____

4.5. If sharecropping, who covered the following expenses?

Human labor_____ Input (fertilizer and seed) _____Ox power_____

4.6. What is the agreement with regard to output sharing?_____

4.7. Decision making with regard to the type of crop that should be grown? 1. Myself 2. The owner farmer

4.8. Type & amount of input that should be used on the plot: 1. myself 2. The owner farmer

4.9. Time of farming activities that should be carried out: 1. myself 2. The owner farmer

5. Wealth condition of the farm households and off/non-farm activities

5.1. What is the relative wealth position of the farmer? (Personal and peer group wealth ranking)

1. Very rich 2. Rich 3. Medium 4. Poor 5. Very poor

5.2. Type of the house 1. Grass cover 2. Corrugated iron 3. Other type_____

5.3. If the house is built with corrugated iron, number of corrugated iron _____

5.4. Do you have any source of income other than farming? 1, yes 2, no

5.5. If the above answer is yes what are the sources of income?

1. Off/non-farm activity 2. Pension payments
3. Constant transfer payment 4. Salary/wage
5. Rent from asset or real estate 6. Other specify

5.6. If you have other source of income, how much average revenue do you get per month and per year? _____Birr per month and _____Birr per year

5.7. Do you participate in non-farm activity? 1, yes 2, no

5.8. If yes, what is the type of activity? List _____

5.9. Why some members of your family are engaged in off/non- farm activities?

1. Shortage of land 2. Excess family labor
3. Attractive income from off-farm activities
4. Other, specify_____

5.10. Is the off/non-farm activity usually done in holidays? 1. Yes 2. No

6. Services

A. Extension Service and Training

6.1. Do you have extension contact? 1. Yes 2. No

6.2. How often does the extension worker visit you?

1. Weekly 2. Occasionally 3. Monthly 4. Quarterly
5. Other, specify_____

6.3. How many times do the extension workers visit you in the production season? _____

6.4. Did you get any practical training over the last three years? 1. Yes 2. No

6.5. Did you ever receive any training outside the locality? 1. Yes 2. No

6.6. If yes, how many times do you received in the production season? _____, the type of training _____duration_____

B. Credit service and saving

6.7. Do you have access to any sources of credit? 1. Yes 2. No

6.8. If yes, what sources of credit do you have? 1. Formal sources 2. Informal 3. Both

6.9. What are the formal sources of credit institutions?

1. Commercial banks 2. Oromia national bank 3. NGOs 4. Others, specify _____

6.9. Have you received any borrowing from the formal institutions this year? 1. Yes 2. No

6.10. If yes, what kind of credit does you received? 1. Short term 2. Medium term 3. Long term

6.11. For what purpose do you borrow?

1. Primary basic needs 2. Medicine 3. School 4. Input purchase 5. Investment 6.To pay back other loans 7. Other, specify _____

6. 12. How much money did you received for the current production year? _____birr

6.13. What is the interest rate? _____%

6.14. What collateral (security) was requested for the credit?

1. Animals 2. Land 3. Durable goods 4. Friends or relatives guarantee

5. Other, specify _____

7. Production activities

7.1. What are major crops you grow? List_____

7.2. What are the major perennial crops you are growing? List _____

7.3. How many plots do you have? _____

7.4. On how many plots do you plant potato 2017/2009 (last year)? _____

7.5. How much of your land is covered by potato crop last year? _____

7.6. What are the major varieties of potato you are growing? Specify_____

7.7. What is the earliest date of land preparation for potato? _____

7.8. What is the latest date of land preparation for potato crop? _____

7.9. At what time did you start land preparation this year? _____.

7.10. How many times did you plough your potato land? _____.

7.11. What is the earliest date of sowing/ planting? _____.

7.12. What is the latest date of sowing/planting potato? _____.

7.13. At what time did you sow /plant potato this year? _____.

7.14. Did you use chemical fertilizer in potato field? 1. Yes 2. No

7.15. If yes, what type of fertilizer?

1. DAP 2. Urea 3. Both 4. Compost/ manure 5. Other, specify_____

7.16. How many Kg of DAP did you use for potato? _____

7.17. How many Kg of Urea did you use for potato? _____

7.18. If you do not use fertilizer, why?

1. Too expensive 2. Inconvenient to transport 3. Not timely available 4. Not available 5. Not good to apply on potato field 6. Other specify_____

7.19. Did you use organic fertilizer on potato field? 1. Yes 2. No

7.20. If yes, what kind of organic fertilizer do you use?

1. Green manure 2.Animal waste
3. Compost 4. Others, specify_____

7.21. How many quintal/ha of organic fertilizer do you apply for your potato crop? _____

7.22. If you are not using organic fertilizer, why?

1. It's bulky to transport 3. I do not have animals to prepare it
2. Lack of awareness 4. Others, specify_____

7.23. Do you have oxen? 1. Yes 2. No

7.24. If yes, how many oxen do you have? _____

7.25. How many oxen do you use from land preparation up to planting? _____

7.26. Do you practice fallowing? 1. Yes 2. No

7.27. If yes, after how many years of harvesting do you fallow your land? _____years

7.28. Then for how long you fallow your land? _____years

7.29. Do you practice crop rotation? 1. Yes 2. No

III. Information on potato output

8.1. Is weeding potato crop a common practice? 1. Yes 2. No
8.2. If yes, when you start weeding potato? _____Week of _____month
8.3. How many times do you weed? _____times
8.4. What method did you use for weeding? 1. Hand weeding 3. Chemicals
2. Hoeing 4.Others, specify_____
8.5. Did you use improved potato varieties this year? 1. Yes 2. No
8.6. If yes, list name of variety and source of seed_____
8.7. If no, why? 1. Too expensive 2. Not better than local varieties
3. It is not easily accessible 4. Other specify
_____

8.8. Do you use crop protection chemicals? 1. Yes 2. No

8.9. If yes, what types of chemicals do you mostly use? List name of chemicals, amount, price and sources.

8.10. If no, why? 1. Too expensive 2. Lack the knowledge of application
3. Not timely available 4. Not available at all 5. Not effective
6. Risky for animals. 7. Other_____

8.11. When did you harvest your potato crop? _____Week of _____month

8.12. How much labour you employed to harvest potato? _____

8.13. From where did you get the additional labour requirement? If any.
1. Family labour was enough 2. Debo/wenfel
3. Employing daily labourers 4. Any other means_____

8.14. How many quintals of potato yield did you received this year? _____Quintal

8.15. How much did you sell it per Kg _____Birr per quintal _____ Birr

8.16. Is there any natural hazard in the production year in the production of potato?
1. Yes 2. No

8.17. If yes, what are these natural hazards? 1. Frost 2. Animal damage 3. Flood
4. Drought 5. Others specify _____

8.18. How much output you would have got, had there were no hazard _____ quintal

8.19. Total requirement of pair of oxen and human participation for different activities

		Pair of oxen		Human labor participation							
				Child		Adult Men			Adult Women		
NO	Activities	No	Hrs	No	Hrs	No	Age	Sex	No	Hrs	Age
1	1st ploughing										
2	2nd ploughing										
3	3rd ploughing										
4	4 thploughing										
5	5 thploughing										
6	Transplanting										
7	Fertilizer application										
8	1 st hoeing										
9	2 nd hoeing										
10	3rd hoeing										
11	Harvesting										
12	Others										

9. Yield and marketing

9.1. For what purpose you produce Potato?

1. For home consumption as food only
2. For home consumption as food but sell in case of emergency
3. For home consumption as food but sell when have in excess
4. For both home consumption as food and sale
5. For sale only
6. Other specify

10. What was the most important problem with regarding to potato production? (Rank according to prevalence)

1. Water logging 2. Low fertility of land 3. Low productivity of local verities
4. Poor land preparation, due to shortage of oxen or other 5. Weed infestation
6. Others, if any_____.