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Analysis of Technical Efficiency of Potato (*Solanum tuberosum*) Production: In the Case of Welmera Districts, Oromia Regional State, Ethiopia

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Abstract
In Ethiopia economy, agriculture sector accounts almost 40.5% of GDP, 81% of exports, and 85 % of the labour force. The other economic activities depend on agriculture, including marketing, processing, and export of agricultural products. Potato is among the major food crops produced in the world in which Ethiopia is also inclusive. In Ethiopia, for example, the total production from potato was 943,233 tons with an average productivity of 13.5 t/ha. The area under potato was 70,132 ha cultivated by 1.4 million households in the main cropping season of 2015/16. During the same period, it ranks first in area coverage and third in both total production and productivity among the root crops grown in Ethiopia. This study was undertaken to estimate technical efficiency level of potato production and to identify the sources of technical efficiency differentials in potato production among members of producers. The required quantitative data were collected through farm household survey using structured questionnaire. For qualitative data, observation, individual and group discussions were the main methods used. Trained field no empirical study that showed analysis of technical efficiency of potato. .With regard to data analysis both descriptive and econometric methods of data analysis were employed. Descriptive statistics such as mean, standard deviation, percentage and frequencies has been used to analyze the socio-economic characteristics of potato production technical efficiency levels of the sample farmers. SPF econometric model that assumed a Cobb Douglas production functional form was employed to analysis technical efficiency level in potato production in the study area. From the results age is one of the important aspects to determine farmers' experience of management of their agricultural production. The survey data showed that the mean age of the sample household heads was 42 years. From the total sample farmers, about 52.9% of them have attended formal level of schooling. From respondents involved in potato production the majorities (83.8 %) were male and 16.7 % were females. There are various factors explain gender difference engaged in potato production. For example, women in rural areas are mostly involved in domestic activities such as collecting water and firewood, caring children at home; preparing food for family etc. The mean total land holding of total sample household in the study area was 3.12 hectare with standard deviation of 1.99 hectare.

***Key words**: Cobb-Douglas, Stochastic frontier, Technical efficiency.*

Introduction

Agricultural production and productivity in Ethiopia is very low and the growth in agricultural output has barely kept pace with the growth in population. In most part of Ethiopia grains production meets the needs of the people including in the deficit areas. But, the inefficient agricultural systems and differences in efficiency of production discourage farmers to produce more (Knife *et al.*, 2012). In Ethiopia highlands potato holds great promise for improving the livelihoods of millions of smallholder farmers. The high yield, early maturity, and excellent food value give the potato crop great potential for improving food security, increasing household income, and reducing poverty (Solomon, 2014). Due to short vegetative period farmers allows finding an appropriate season for its cultivation under a wide range of weather patterns and less predictable climates. As a result, the combined area planted to potato in Ethiopia for both Belg (short rainy season - February to May) and Meher (long rainy season - from June to October) growing seasons is about 179,000 ha (CSA, 2014). In spite of its popularity, the productivity of the crop is relatively low (CSA, 2014). There are many factors contribute to the low yield, including drought, frost, poor production practices and limited access to high quality seed (Doss *et al.*, 2008; FAO 2010, Bekele and Eshetu, 2008, Gildemacher *et al.*, 2009; Hirpa *et al.*, 2010).

In Ethiopia, potato is grown in four major areas: The Central, the Eastern, the North-Western and the Southern regions, which together constitute approximately 83% of the potato farmers in the country (CSA, 2011). In the Central area, potato production includes the highland areas surrounding the capital, i.e. Addis Ababa. In this area the major potato growing zones are West Shewa and North Shewa About 10% of the potato farmers are located in this area (CSA, 2009). In the central area potato is produced mainly in the belt (short rain Season-February to May) and meher (long rain Season-June to October) periods. Potato is also grown off-season under irrigation (October to January). Because of the cool climate and access to improved varieties, farmers in this area of the country also produce potatoes which are sold to other farmers in the vicinity or to NGOs and agricultural bureaus to be disseminated to distant farmers. In the central area, farmers grow about seven local varieties, eight improved varieties and six clones (i.e. genetic material which is not officially released) (Adane *et al,* 2010).

The Eastern area of potato production mainly covers the Eastern highlands of Ethiopia, especially the East Harerge zone. However, the area is identified specifically because the majority of the potato farmers' in this region produce potatoes for the market and the farmers have also access to export markets in Djibouti and Somalia. Potato is mainly grown under irrigation in the dry season (December to April). This season is characterized by low disease pressure and relatively high prices (Eshetu *et al*, 2005). The North-Western area of potato production is situated in the Amhara region. It is the major potato growing area in the country, accounting for about 40% of the potato farmers (CSA, 2011). South Gonder, North Gonder, East Gojam, West Gojam and Agew Awi are the major potato production zones in this region. The Southern area of Ethiopia in which potato is grown, is mainly located in the Southern Nations', Nationalities' Potato Production System (SNNPRs) comprises all processes and activities (land preparation through harvesting) undertaken to produce ware or seed potatoes and Peoples' Regional State (SNNPRs) and partly in the Oromiya region. The major potato producing zones in this area are Gurage, Gamo Goffa, Hadiya, Wolyta, Kambata, Siltie and Sidama in the SNNPRS and West Arsi zone in Oromiya. More than 30% of the total number of potato farmers is located in this area (Tesfaye and Leeuwis, 2009). The low acreage and productivity of potato in Ethiopia are attributed to many factors. The major ones are lack of well adapted and high-yielding cultivars, unavailability and high cost of seed tubers, inappropriate agronomic practices, and lack of marketing and suitable post-harvest management facilities, insect pests and disease (Endale and Lemaga, 2008; Gildemacher *et al,* 2009). Also Fuglie (2007) described that lack of varieties with stable and high yield potential, lack of good quality seeds, disease and insect pest problems, drought and seed dormancy to fit the local cropping calendar, lack of improved characterization and exist conservation of potato genetic resources are very important limitations to potato production by smallholder farmers in sub-Saharan-Africa. Several varieties of potato are grown by farmers some of which are local and others are improved varieties. According to Tekalign, (2005), 98.7% of the seed tubers required in Ethiopia are supplied from the local varieties. The seed tubers supplied by this system have poor sanitary, physiological, physical and genetic qualities (Berga *et al*, 1994)

The yield gap between attainable and potential yield of potato in Ethiopia is very high. A study by Aliye *et al* (2008) in Ethiopia on bacterial wilt find out that disease is one of the most important factors that contribute to this high yield gap in the country. According to them, the contribution of diseases to the gap between the production potential and the current average national production takes a large part since potato crop is susceptible to a number of diseases including late blight, viruses and bacteria wilt. The same study indicated that mid-altitude areas of the country around Shashamene, Bako, Jima and Rift Valley are most affected by bacterial wilt.

Materials and Methods

Description of the Study Area

Welmera is one of the districts in the Oromia Region of Ethiopia. It is one of the Oromia special zones surrounding Addis Ababa. It is bordered in the south by the Sebeta Hawas, in the west by Ejere Woreda of West Shewa Zone, in the north by Mulo, in the northeast by Sululta district of North Shoa zone and in the east by Burayu town administration. The highest point in this district is Mountain Wechacha 3191 masl located in the southern part of the district. The rainfall pattern of the district is bimodal, with a short rainy period from February to April and a long rainy season from mid June to September. The annual temperature and rainfall ranges from 18°C to 24°C and 1000 to 1100 mm, respectively. It covers a total area of about 85,657 hectares. Plain undulating slopes and mountains characterize the topography of the area (WWADO, 2013). The topography of the district is mainly plain. The major crops grown in the area are potato, teff, wheat, lentils, cereals and pulse crops. The soil type is mainly black clay, red and sandy. Potato grows in both 'red and black' soil types. In addition to crop production, livestock production is also common in the area. Livestock production in the area is the source of draft animal power for ploughing and threshing, source of income next to crop production, and it serves as a risk minimization strategy during crop failure as one source of fuel. According to the Census of 2007, the population of the district reported a total population for this woreda of 83,823, of whom 42,115 were men and 41,708 were women; 3,352 or 4% of its population were urban dwellers. The majority of the inhabitants said they practiced Ethiopian Orthodox Christianity, with 86.72% of the population reporting they observed this belief, while 6.36% of the population practiced traditional beliefs, and 4.61% were Protestant(WWADO, 2013).

Sampling Procedure and Techniques

In order to conduct this study out 44 kebeles, four kebeles were selected purposively based on their production of potato in 2016 year, and use of modern technology for their production in a year and supply of potato product into a local market.

Sample Frame

The sample frame for this study was the household from four kebeles of the woreda. Those four kebeles comprises of 8228 households. Based on this household size proportional sampling was done to make representative from each kebele. Proportionality was calculated from the total households of those four kebeles and based on this percentage their respective sample size was taken.

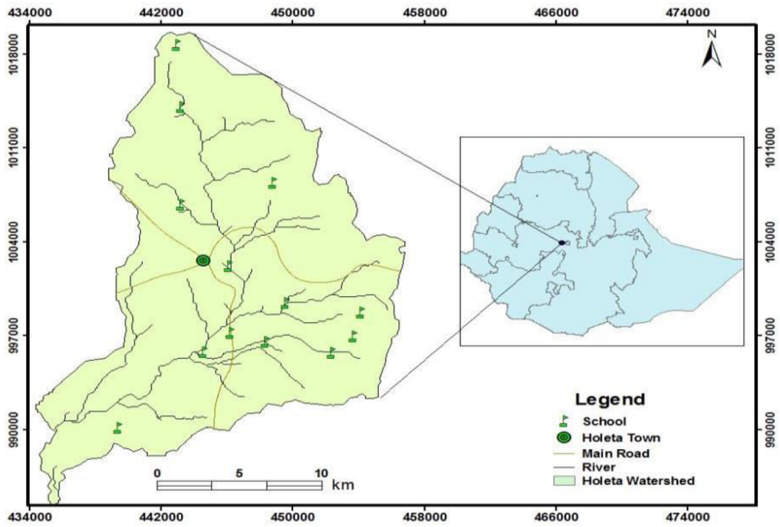

Fig 1: Map of the Study Area

Table: 1: Population of sample size.

TL	Name of kebele	HH No	Proportionality	Sample amount from 136 HH
1.	Rob- Gabeya	2,330	0.28	136*0.28=39
2.	Tullu Harbu	2,300	0.27	136*0.27=39
3.	Talecho	1,558	0.18	136*0.18=25
4.	Bakkaka and Koree Oddoo	2,040	0.24	136*0.24=33
	Total	**8,228**		**136**

Sample Size Determination

Again, from four selected kebeles the respondents were selected in a representative way to increase its reliability and validity of the samples. Accordingly, the sample size of the study or the number of respondents was determined by using (Kothari, 2004) sampling design formula:

$$n = \frac{z^2 pqN}{e^2(N-1) + z^2 pq}$$

Where

n= Sample size

N=total population (8,228)

Z=95% confidence interval under normal curve (1.96)

e= acceptable error term (0.05) and P and q are estimates of the proportion of population to be sampled (P=0.1 and q= 0.9)

To get p and q values a pre-test was undertaken on 10 households in the study area. From 10 households only 1 of them is not produced potato, and 9 of them produced potato crop. Therefore, the value of p is 0.1 and value of q is 0.9. Thus, according to the above formula, the numbers of respondents calculated were 136. Those 136 respondents were selected randomly by using simple random sampling technique (lottery method) considering the proportionality to their population size from four kebeles selected. Accordingly, from Rob-Gabey kebele 39, Tullu Harbu 39, from Talecho 25 and from Bakkaka and Kore Oddo 33 households' respondents were selected from each.

Sources of Data and Methods of Data Collection

For this study, both primary and secondary data were used. Structured questionnaire was used to collect primary data from sample households. The questionnaires were first pre-tested on selected respondents and on the basis of the results of the pre-test, necessary modifications were made before carrying out of the actual survey. After the pretest, the questionnaire was modified and used in face-to-face interview of 136 households. Information was collected regarding potato production in 2016 cropping year. All households selected using random sampling from the selected villages were visited and face to face interviews carried out. In each of the selected potato producing households, the household head or any adult who had lived with the household for at least one previous crop production seasons and was conversant with the farming activities of the other household members was interviewed. The primary data were supplemented by secondary data whenever necessary.

Methods of data collection

The required quantitative data were collected through farm household survey using structured questionnaire. For qualitative data, observation, individual and group discussions were the main methods used. Trained field enumerators were involved in data collection. They were then administered by the researcher with the help of four enumerators recruited among (DA) Development Agents. The DAs were chosen as enumerators because they not only had a good knowledge of rural areas, but were also well known to the farmers. Prior to an interview, the objective of the survey was clearly explained to the respondents. In every farm, the head of the household, who was considered as the farm manager, was interviewed.

Methods of Data Analysis

With regard to data analysis both descriptive and econometric methods of data analysis were employed. Descriptive statistics such as mean, standard deviation, percentage and frequencies has been used to analyze the socio economic characteristics of potato production technical efficiency levels of the sample farmers. SPF econometric model that assumed a Cobb Douglas production functional form was employed to analysis technical efficiency level in potato production in the study area.

Descriptive Analysis

This method is used to summarize and analyze the sample household input use, output levels and their socio-economic characteristics, used in the frontier production and in the (in) efficiency model, respectively.

Econometric Analysis

Specification of the Empirical Econometric Model

In this study the stochastic production frontiers were used for its key features that the disturbance term is composed of two parts, symmetric and a one sided component term. The symmetric component captures the random effect of the decision maker including the statistical noise contained in very empirical relationship particularly those based on cross section household survey data. The one sided component captures deviation from the frontier due to inefficiency. The biggest advantage of the stochastic production frontier models is the introduction of a disturbance term representing noise, measurement error and exogenous shock that are beyond the control of the production unit in addition to the efficiency components. Hence technical efficiency measure obtained from stochastic frontiers is expected to reflect the true ability of the farmer given the resources. The assumption that all deviation from the frontier are associated with inefficiency as assumed in DEA, is difficult to accept, given the inherent variability of agricultural production due to a lot of factors like weather, insect pests, diseases, etc. (Coelli and Battese, 1995). Furthermore, because of the low level of education and high illiteracy among farmers in developing countries, keeping accurate records is not a common practice. Thus, most available data on production are likely to be subject to measurement errors. Small holder farmers in Ethiopia in general and in the area in particular are characterized by low level of education of keeping of records is thus non-existent. Moreover, there is high variability of agricultural production due to weather fluctuations. Therefore, within the stochastic frontier frame work, the stochastic efficiency decomposition methodology is chosen as more appropriate for this study. The stochastic frontier method requires a prior specification of the functional form, between Cobb-Douglas and Translog. However, recent advances in developing new functional forms have been dominated by efforts to conceive “flexible” from. As a result, flexible functional forms such as the Translog form are usually recommended rather than the restrictive Cobb-Douglas form (Greene, 1980). The Translog function is the only one of the flexible functional forms that is readily used for direct estimation of the production function. In fact, in this study the likelihood ratio test was conducted to select the appropriate functional form that best fits the data. The value of the generalized likelihood ratio (LR) statics to test the hypothesis that all interaction terms including the square specification is equal to zero $(H_0: \beta_{ij} = 0)$is calculated as;

$$LR = -2(L_C - L_T)$$

Where;

LR=generalized log likelihood ratio

L_C =*log likelihood values of Cobb –Douglas frontier; and*

L_T =*Log-likelihood* β *value of Translog frontier;*

This value is then compared with the upper 5% point for the X^2 distribution and the decision is made based up on the model result. If the computed and the test are bigger than the critical value, the null hypothesis will be rejected and the Translog frontier production function better represents the production of farmers. Simple correlation analysis was used for checking the presence of a serious problem of multicollinearity and the variables are select accordingly.

The farm’s technology is represented by a stochastic production frontier as follows;

$$Y_i = f(X_i; \beta) + e_i$$

Where Y_i *denotes output the farm;* X_i *is a vector of functions of actual input quantities used by the* i^{th} *housed hold ;* β *is a vector of parameters to be estimated and* e_i *is the composite error term* (Aigner *et al.,*1977; Meeusen and Van Den Broeck 1977) defined as

$$e_i = V_i - U_i$$

Where; V_i are assumed to be independently and identically distributed $N(0,\sigma^2)$ random errors independent of the μ_i; and the distribution assumption of the technical inefficiency term, U_i is estimated using the likelihood ratio test.

The subtraction of μ_i; from V_i; implies that the logarithm of production function is smaller than it would otherwise be if technical inefficiency did not exist.
The above parametric models are estimated in terms of the variance parameters.

$$\sigma^2 = \sigma^2 V + \sigma^2\mu \text{ and } \gamma = \frac{\sigma^2\mu}{\sigma^2 V + \sigma^2\mu} \text{ And } 0 \le \gamma \le 1$$

The parameter γ measures the discrepancy between frontier and observed levels of output and is interpreted as the total variation in output from the frontier attributable to technical inefficiency. It has a value between zero and one. The value of zero indicates that the non-negative random variable , u_i , is absent from the model while the value of one shows the absence of statistical ''noise '' or exogenous ''shocks'' from the model and hence low level of farm's production compared to the ''best '' practice (the maximum output)of the other farm that is totally a result of farm specific inefficiency. More formally, to test whether technical inefficiency is absent and hence the conventional (average) production function is appropriate or not we can use the likelihood ratio test using the log likelihood values is of the OLS and the MLE. Given the specification of the stochastic frontier production function as defined by equations above the technical efficiency of the i^{th} farmers is

$$TE_i = EXP(-u_i)$$

Where u_i are non-negative random variable, which are assumed to be independently distributed with mean u_i and variance $\sigma^2\mu_i$.

The Cobb- Douglas full frontier in its logarithmic form is specified as follows:

$$\ln Y_i = \beta_0 + \sum \beta_i \ln x_i + e_i$$

The Translog full frontier in its logarithmic form is specified as follows in logarithm natural

$$\ln Y_i = \beta_0 + \sum \beta_i \ln x_i + \frac{1}{2}\sum \beta_{ij} \ln x_i \ln x_j + e_i$$

$$\ln Y_i = \beta_0 + \beta_1 \ln S_i + \beta_2 \ln F_i + \beta_3 \ln L_i + \beta_4 \ln P_i + \beta_5 \ln C_i + \beta_6 \ln A_i + (v_i - u_i)$$

Where;
Y_i= *Quantity of output of potato production in kg*
L=Amount of labor
P= Power in oxen
A=Area planted with potato production in ha
S=Amount of seed used in kg
F= is measured as the total fertilizer used in potato production in kg
β_i= *parameters to be estimated*
V_i= *symmetric component of error term;*
U_i=*inefficiency components of error term; and*
i= *number of farmers (1-136 sample respondents)*

The technical efficiency effect model (Coelli and Battesse, 1995) in which both the stochastic frontier and factors affecting inefficiency are estimated simultaneously is specified as follows.
In Cobb-Douglas functional form

$$\ln Y_i = \beta_0 + \beta_1 \ln S_i + \beta_2 \ln F_i + \beta_3 \ln L_i + \beta_4 \ln OL_i + \beta_5 \ln C_i + \beta_6 \ln A_i + v_i - (d_0 + d_1 Lv_i + d_2 Xvt_i + d_3 Ed_i + d_4 Fm_i + d_5 Ag_i + d_6 Agsq + d_7 Fr_i + d_8 Cr_i + d_9 N_i + d_{10} OFF_i + d_{11} Se_i + d_{12} FS + W$$

In Translog function from

$$\ln Y_i = b_0 + b_1 \ln L_i + b_2 \ln p_i + b_3 \ln A_i + b_4 \ln S_i + \frac{1}{2}[b_5 \ln L_i^2 + b_6 \ln P_i^2 + b_7 \ln A_i^2 + b_8 \ln S_i^2 + b_9 \ln L_i \ln p_i + b_{10} \ln L_i \ln A_i + b_{11} \ln L_i \ln S_i + b_{12} \ln P_i \ln A_i + b_{13} \ln P_i \ln S_i + b_{14} \ln A_i \ln S_i] + v_i - (d_0 + d_1 Lv_i + d_2 Xvt_i + d_3 Ed_i + d_4 Fm_i + d_5 Ag_i + d_6 Agsq + d_7 Fr_i + d_8 Cr_i + d_9 N_i + d_{10} OFF_i + d_{11} Se_i + d_{12} Pr_i + d_{13} FS) + W$$

Where;
$Y_i, \ln, \beta_i, L_i, A_i, S_i$, and v_i *are defined as in equation above*
Lv= *Livestock holding*
Cr = Access to credit
$Agsq$= *Age Square*

Xt= Extension Contact
Fm= Family Size
Ag= Age of farmers
Fs= Fertility Status
OFF= off farm activity
Se= Sex of the household head
Fr= farm size
Ed=level of education
di=parameter vector to be estimated
wi=Error term; and others are squares and interactions terms

The ML estimates of technical efficiency effects of the model given above will be estimated using a software package FRONTIER VERSION 4.1(Coelli, 1996) which is specifically designed for the estimation of efficiency.

Results and Discussion

This chapter is divided into two main sections namely descriptive statistics and econometric results. In the first section, results of the descriptive analysis of the socio-economic characteristics, demographic characteristics, and agricultural activities of the sample farmers are presented. In the second section, econometric results of technical efficiencies and their determinants were estimated and identified for potato producing farmers under the area.

Descriptive Results and Discussion

Demographic characteristics of the sample households

Age is one of the important aspects to determine farmers' experience of management of their agricultural production. The survey data obtained from the study showed that the mean age of the sample household heads were 42 years with standard deviations of 8.4 and the maximum and minimum of the household were 65 and 26 years respectively. According to Teshager (2015) age is a variable included to estimate the impact on efficiency. He concludes that, age can serve as a proxy for farming experience. Hence, higher the age, the greater the farming experience.

Farmer's level of education is expected to influence his ability to adopt agricultural innovations and make decisions on various aspects of farming. Education is therefore highly important for sustainable agricultural growth and development**.** The education levels of selected potato farmers for this study ranged from zero (illiterate) to diploma level (Appendix 4 table 14). In the study area, the average years of formal schooling of sample farmers were found to be 3.08 (grade 1-6) years with standard deviations of 2.04. From the total sample farmers, about 52.9% of them have attended formal level of schooling.
The total number of families and their composition within household determine the availability of labor power needed in the farm production. However, as population increases land per capita will decline and therefore need to improve the productivity and efficiency of farmers. In the study area, average family members of the sample were 1.8 (Appendix 5 table 15) with standard deviations of 0.783.

Table 2: Demographic characteristics and education of the household heads

Descriptive Statistics					
	N	Minim	Maxim	Mean	Std. Deviation
Age of the household	136	26.00	65.00	42.4706	8.48610
Education level of house head	136	1.00	8.00	3.0882	2.04567
Number of family	136	1.00	5.00	1.8750	.78351
Valid N (list wise)	136				

From 136 household respondents involved in potato production the majorities (83.8 %) were male and 16.7 % were females. Bagamba (2007) contends that men are capable of doing more tedious work which is usually associated with farming than the females. He also asserts that farms managed by men were expected to attain higher technical efficiency than those were managed by women. Some earlier studies (Teshager, 2015) at Bahirdar University indicated that male-headed households use their production inputs efficiently. There are various factors explain this gender difference engaged in potato production. For example, women in rural areas are mostly involved in domestic activities such as collecting water and firewood, caring children at home, preparing food for family etc. Therefore, it may not be easy for women to afford extra time to do field activities.

Table 3: Sex characteristics of the household heads

Variable	Category	Frequency	Percent
Sex of household	Male	114	83.8
	Female	22	16.2
	Total	136	100

Resource basis

Land holding: Land is the primary and dependable means of living for the rural people of the country as a whole. The land reform of principle are a farmers have only use-right (i.e. farmers have no right to sell the land at their holding). But, farmers shared-out their farm land in cases when a given farm land is too far from the residence of the farmer, when he/she had shortage of draft animals and labour and/or not suitable to the crops, which the owner commonly grown. On the other hand, when farmers had shortage of land, enough pairs of oxen and labor to plough more land, they shared-in land. Therefore, the mean total land holding of total sample household in the study area was 3.12 hectare with standard deviation of 1.99 hectare. The minimum and maximum land holding were 0.5 hectare and 10 hectare, respectively. These average lands holding of the sample households were more than the woreda average land holding size which is 2.5 ha (WOA, 2013). The average size of land allocated for potato in the study area in the production year was about 0.41 ha with a minimum and maximum of 0.16 hectare and 1hectare, respectively.

Livestock holding: The smallholder farmers in the study area have also engaged in animal husbandry beside agricultural production. They kept animals mainly as sources of traction (adhesive friction) that is food in the first place as meat, milk, cheese, butter, egg, source of income, and manure for soil fertility maintenance and transporting goods. Hence, livestock holding was an important variable in expressing the wealth position of the farmer in augmenting his/her income. Livestock, specifically cattle are as equally important components of the farming system as that of basic food crop production in the area. Donkeys and horses are used for transporting loads and human beings. Small ruminants are used to meet immediate cash demand of the households and also for meat production for household consumption especially during holidays. Poultry are kept for egg and meat production both for cash and home consumption. Hence, farm household who has more livestock can have more income that help him/her to purchase improved agricultural inputs which in turn enhance crop production and productivity and efficiency level of the potato producer. In general, the average livestock holding was 8.07 TLU, with standard deviation of 4.03 TLU (Table 4).

Table 4: Distribution of the sample farmers by resource basis

	Descriptive Statistics					
Variables	N	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
Total land holding	136	.50	10.00	3.1232	.17068	1.99049
TLU	136	2.13	19.42	8.0715	.34618	4.03715
Land allocated (hec)	136	.16	1.00	.4101	.01832	.21366
Valid N (list wise)	136					

Cropping system: Grain production constitutes the major share of agricultural production and contributes significantly to the national domestic product, in Ethiopia (Abu and Quintin, 2013). Small land holder farmers produce around 98 percent of cereals. Given the importance of agricultural and field crop production in particular, improving efficiency and productivity in crop production can result in a large increase in total household income. Crop production of the woreda is limited to meher season and the major types of crop that are produced includes wheat, teff, barley and Bean from cereals, and horse beans, haricot bean, chickpeas and field peas from pulses. Some smallholder farmers are engaged in irrigated agriculture using water source from the lake, river and underground water for farming some cereals and horticultural crops.

Social services

Extension services:- it is expected to have direct influence on the production of the farmers. The higher access to the extension service, the more likely that farmers adopt new technology and innovation. To this end, the government has been attempting to fill the required knowledge and achieve food self sufficiency in the country by placing in each Kebele administration three development agents (DAs) and building a farmer training center (FTC). The kebele level development agents are the most important sources of extension services to transfer agricultural technologies and innovations to farmers. The effort to disseminate new agricultural technologies is influenced by the efficiency of communication between the development (change) agent and the farmers at grassroots level. The survey result indicated that the most farmers meet extension work weekly 61(44.9%) and monthly 59(43.4%). They also meet at farm place 58(42.6%) and at office 28(20.6%).

Table 5: Frequency of extension agent meets the farmers

Variable	Category	Frequency	Percent
Access to extension service	Daily	10	7.4
	Monthly	59	43.4
	Weekly	61	44.9
	Quarterly	2	1.5
	As we want	4	2.9
	Total	136	100
Place of visit	At his office	28	20.6
	At farm	58	42.6
	At public meeting	10	7.4
	At his office and farm	12	8.8
	At office meeting and office	18	13.2
	At farm and public meeting	6	4.4
	Were ever we want	4	2.9
	Total	**136**	**100**

Credit: The results of the study in table 6 showed that, the majority (97.1%) of the respondents did not have access to any form of credit, while only 2.9% of the farmers had access to credit. Access to credit improves problem of liquidity and enhances use of agricultural inputs in production. Lack of credit facilities affected inputs acquisition especially among cash constrained farmers. Farmers' accessibility to credit through credit cooperatives can reduce constraints encountered in production hence increasing the efficiency of farmers.

Table 6: Distribution of access of credit

Variable	Response	Frequency	Percent
Access to credit	Yes	4	2.9
	No	132	97.1
	Total	136	100

Estimation of Stochastic Frontier Production

Hypotheses test

Before proceeding to the analyses of technical efficiency and its determinants, it was necessary to select the appropriate functional form and detect the presence of inefficiency in the production of potato for the sample households.

The Cobb-Douglas and the Translog functional forms are the most commonly used stochastic frontier functions in the analysis of technical efficiency in production. The Translog frontier function turns into Cobb-Douglas when all the square and interaction terms in the translog are zero. In order to choose between the two alternative functional forms that can better fit to the survey data collected, the null hypothesis that all the interaction and square terms are all equal to zero ($H_0 : \beta_{ij} = 0$), i.e. Cobb-Douglas frontier functional specification, is tested against the alternative hypothesis that these coefficients are different from zero ($H_1 : \beta_{ij} \neq 0$). For the respondents the estimated log likelihood values of the Cobb-Douglas and Translog production functions were 12.05 and 38.63, respectively. Therefore, the generalized likelihood ratio test is used to decide appropriate functional form based on the following log likelihood ratio test:

$$LR(\lambda) = -2[\{lnL(H_o)\} - \{lnL(H_1)\}]$$

The computed values for LR = 53.16 is lower than the upper 5% critical value of the χ^2 with their respective degree of freedom (Table 8). Thus, the null hypothesis that all coefficients of the square and interaction terms in Translog specification are equal to zero was not rejected. This implies that the Cobb-Douglas functional form adequately represents the data under consideration.

Table 7: Generalized likelihood-ratio test of hypotheses for parameters of SPF

Null hypothesis	Ho	LR (λ)	Critical value X^2	Df	Decision
H_0: $\gamma = 0$	12.05	53.16	61.66	39	Accepted H_0
H_0: $U_i = \delta_0 = \delta_1 = \ldots = \delta_{11} = 0$	-63.84	30.50	15.41	10	Reject H_0
H_0: $\sum\beta_I = 1$	-41.06	67.46	3.84	1	Reject H_0

Therefore, before embarking on to estimation of the final model, some tests are carried out. The hypotheses that whether there is inefficiency in the production of potato was tested against the null hypothesis, H_0: $\gamma = 0$, where the parameter, $\gamma = \sigma^2/(\sigma^2 + \sigma_v^2)$, such that there is no inefficiency in the production of potato. If the null hypothesis is true, the SPF will be equivalent to the average response function. Hence in this case, if there is output difference among farmers given equal inputs, the difference is purely due to random errors that are outside of the control of the farmer. This hypothesis can be tested using the generalized likelihood ratio test based on the log likelihood function under OLS estimation and final maximum likelihood estimation.

The generalized likelihood ratio statistics, $\lambda = 53.16$, presented in Table 8is found to be less than the critical value of 61.66. Hence we can reject at 1% level of significance the null hypothesis that the average response function (OLS specification) is not an adequate representation of the data. Consequently, the null hypothesis that potato farmers in the area are efficient is rejected. Hence there is considerable inefficiency among farmers in the production of potato in the study area. The other closely related to the above hypothesis is what proportion of the existing inefficiency can be represented by deterministic frontier model. The p-value of 0.000 in Table 9 clearly shows that $\gamma = 0$ is strongly rejected at one percent significance level. From this value it can be calculated that the relative deviations from the frontier due to efficiency γ is equal to 0.86 or 86%. This indicates that large parts of the deviations are due to efficiency and 14% of the deviations are due to noise or random error. This shows that the stochastic frontier model is not highly different from the deterministic model specification in which there is no random error in the production. This is of course unexpected result that most agricultural studies are heavily influenced by noise in the data.

The next hypothesis is that the null hypothesis that the explanatory variables associated with technical inefficiency effects model are all zero, H_o: $U_i = \delta_0 = \delta_1 = \delta_2 \ldots = \delta_{11} = 0$. To test this hypothesis likewise, λ, was calculated using the value of the log likelihood function under the stochastic 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 λ = 30.50 is greater than the critical value of 15.41 , thus the null hypothesis that variables in the inefficiency effects model are simultaneously equal to zero is rejected at 1% level of significance. 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.

The last test of hypothesis of interest is the test for returns to scale. We can divide the dependent variable output by land size and all independent variables was then be divided by the same variable land size to get constant return model specification. The result of the estimation made under both model specifications, under constant returns to scale and variable return to scale, shows that the log-likelihood function is equal to –41.06 and –73.79, respectively. Thus, the log likelihood-ratio test is calculated to be 67.46 and when this value is compared to the critical value of 3.84, the null hypothesis that the production system is characterized by constant return to scale is strongly rejected. The estimation result presented in Table 10 shows that the return to scale is equal to 1.08. In this case the return to scale is increasing returns to scale. Thus the production structure, given these inputs, is characterized by increasing returns to scale.

Technical Efficiency Analysis

The main objective of this study was to measure the technical efficiency levels of potato producing farmers in Welmer Woreda**.** From the analysis of the survey data, efficiency indices obtained vary from one potato farmer to another in a range from 0.64 to 0.97; with an average of 0.86 (Annex 1). According to the results, 14% of potato output on the average was lost due to the specific inefficiencies pertaining to farms. This suggests that on average farmers can increase their current level of output by 14% without increasing the existing levels of inputs they are using. Alternatively, the result indicated that farmers on the average could decrease their current levels of inputs by 14% to obtain the existing level of potato output. Furthermore, there is a large difference in technical efficiency scores among the sample households that ranged from 0.64 to 0.97. A frequency distribution shows that 33% of the potato producing sample farmers is found within the range of technical efficiency scores. This indicates that farmers by far the largest portion of error variation is due to the inefficiency error u_i and not due to the random error v_i implying that the random component of the inefficiency effects does make a significant contribution in the analysis. This means that technical inefficiency is likely to have an important effect in explaining output among farmers in the sample.

It is observed that the MLE estimate of γ is 0.867 with estimated standard error of 0.012 (Table 8). This is consistent with the theory that the true γ-value should be greater than zero and less than one. The value of the γ-estimate is significantly different from one, indicating that random shocks are playing a significant role in explaining the variation in potato production, which is expected especially in the case of agriculture where uncertainty is assumed to be the main source of variation. This implies that the stochastic production frontier is significantly different from the deterministic frontier, which does not include a random error. However, it should be noted that 86% of the variation in yield is due to technical inefficiency and only 14% is due to the stochastic random error.

Table 8: Maximum-likelihood estimates of the frontier model

Variable	Parameter	Coefficient	Std. Error	P- value
Dependent variable: ln(potato productivity)				
Stochastic Frontier Production function				
Constant	β_0	1.69	.80	0.035*
Ln(seed)	β_1	.71	.07	0.000***
Ln(Total fertilizer used)	β_2	.08	.05	0.123
Ln(Labor)	β_3	.34	.09	0.000***
Ln(Oxen labor)	β_4	-.29	.12	0.017*
Ln(Chemical use in birr)	β_5	.11	.05	0.004**
Ln(Land)	β_6	.13	.10	0.193
Sigma-squared	σ_s^2	1.44	.20	0.000***
Gamma	γ	.86	.01	0.000***
Log-likelihood function		-73.79		

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

On the average, as the increment of the variables such as, seed quantity, labor force and chemical by one percent will increase output by 0 .71, 0.34 and 0 .11 percent respectively. From Table 9, the study identified that seed; labor and chemical are positively related to potato output. Given that other factors are the same, if there is a unit increase in seed; potato yield will increase by 0.71. The positive relationship between potato yield and seed is in conformity with literature and the expectations of the study. This substantiates the fact that increasing seed will be accompanied by large volume of potato output. Similarly, a unit increase in the amount of chemical will cause potato yield to increase by 0.05 assuming that other variables are held constant. The positive relationship between chemical used and potato yield is in line with the literature and the expectations of the study. This is true because chemical prevents weeds from competing with crops for soil nutrients thereby providing better yield. On the other hand, as we increase the number of oxen-days in the course of land preparation through planting by one percent, potato yield will tend to decrease by 0.29 percent. The reason might be due to low opportunity cost for having a pair of oxen in the area, farmers over utilized the oxen power. Over plowing coupled with high temperature may also led to soil moisture lose, which may in turn has direct effect on suppressing seed germination. Therefore, these inputs have significant impact in determining the output level of production; the increase in these inputs would decrease output of potato. The positive values imply that the present inputs used were not optimal and yields would have increased from the additional use of inputs. Coelli *et al,*. (1998) argues that stage I is inefficient because the addition of an extra unit of firm should never produce. On the other hand, negative values indicated that the input use has reached the maximum level and more use of such input beyond the current level would lead to reduced yields.

Determinants of technical efficiency

The driving force behind measuring farmer's efficiency in potato production is the identification of important variables/determinants with which to work for development in order to improve the existing level of efficiency. The parameters of the various hypothesized variables in the technical inefficiency effect model that are expected to determine efficiency differences among farmers were estimated though MLE method using one-stage estimation procedure. The determinants of technical inefficiency/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. Table 10 shows the result of the technical inefficiency model estimates. Among the eleven explanatory variables entered in the inefficiency effect model in the analysis three variables namely, age, improved seed and family size have appeared with unexpected signs, and all of them are statically significant. The result of the remaining inefficiency variables conforms to the priori expectations in their signs, of which Credit serves, fertility status, Irrigation and extension contact are statically insignificant. Before discussing the significant determinants of inefficiency in potato production it is important to see how efficiency and inefficiency are interpreted. The result can be presented in terms of efficiency or in terms of inefficiency. The result in the table is presented in terms of inefficiency and hence the negative sign shows the increase in the value of the variable attached to the coefficient means the variable negatively contribute to inefficiency level or conversely it contributes positively to efficiency levels. Thus any negative coefficient happens to reduce inefficiency which implies its positive effect in increasing or improving the efficiency of the firm vice versa.

Table 9: Determinants of technical inefficiency

Variable	Parameter	Coefficient	Std. Error	P- value
Constant	δ_0	5.155	.110	0.018*
Age	δ_1	-.008	.009	0.005**
Age2	δ_2	.028	.032	0.084*
Sex of HH	δ_3	-.456	7.372	0.000***
Education of HH	δ_4	-.647	1.531	0.082*
Family size of HH	δ_5	.034	.538	0.055*
Off- farming activities	δ_6	-.853	6.379	0.000***
Extension serves	δ_7	.007	3.894	0.272
Credit serves	δ_8	.937	1.295	0.787
Total land holding	δ_9	.149	1.608	0.000***
Irrigation	δ_{10}	.620	6.378	0.134
Fertility status	δ_{11}	.546	2.142	0.276
Improved variety	δ_{12}	-.916	7.691	0.003**
Sigma-squared	σ_s^2	1.44	.20	0.000***
Gamma	γ	.86	.01	0.000***
Log-likelihood function		-73.79		
Return to scale		1.08		
Mean of technical efficiency	TE	86.7%		

,,& *** show significant at 10%, 5% & 1% respectively*

Accordingly, the data obtained the negative and significant coefficients of family, age, sex, education and improved seed indicate that improving these factors contribute to reducing technical inefficiency. Whereas, the positive and significant variables such as, family size, age square and total land affect the technical efficiency positively that increases in the magnitude of these factors aggravate the technical efficiency level. The implications of significant variables on the technical efficiency of the farmers in the study area are discussed here under.

Age: In the study area, the mean age of the sample farmers was 42 years. Age of the farmers can have direct relationship with experience in farming as well as capacity to work on those laborious farming activities. To compare the existence of technical efficiency differential among different age groups, sample farmers were arbitrarily classified in to three age groups. The classification for this result could be that old age group lack the capacity to work energetically and they become conservative to adopt new technologies even if they have good experience farming. Farmers below the age of 30 also lack experience and motivation towards farming since their mean technical efficiency was found lower than the succeeding age group. In the other hand, farmers of the middle age group are relatively more energetic and adopt technologies compared to old farmers and have relatively more experience and motivation than the youngster.

The result supports the hypothesis that there is efficiency difference among farmers of different age groups. The coefficient of age variable was statistically significant at 5% probability level. It was found out that age of the farmers is related quadratic to the level of technical efficiency in potato production with the signs of the coefficients negative for the age and positive for the age-square. It implies that the middle age groups of sample farmers are more efficient and efficiency starts to decline after certain age level as one gets older. Similar results were obtained in different studies (Endalkachew, 2012; Shumet, 2012).

Gender: The coefficient for gender is dummy and significantly negative at1% level of significance as was expected, indicating that male headed households operating more efficiently than their female counterparts. This result is in line with the study by Wudineh, (2013); Kibaara and Kavoi *et al.,* (2012), and it is in contrast with the study by Yami *et al.* (2013) in selected waterlogged areas of Ethiopia.

Education: The educational level of farmers has a negative and significant effect on technical inefficiency. The inverse relationship between technical inefficiency and farmer level of education may be explained by the fact that farmers who had spent many years in formal education tend to be more efficient in potato production. Better performance by more educated farmers may be attributed to the fact that they may have better access to new information, more receptive to adoption of yield-improving farming techniques and may readily respond to the use of improved technology such as fertilizers, pesticides and improved planting materials. This finding is consistent with results of other studies. For example, Fekadu (2004) in his study on the analysis of technical efficiency of wheat production that education negatively influences production efficiency. According to Bozoglu and Ceyhan *et, al.,* (2007) education increases the ability to perceive, interpret and respond to new events and enhances farmers' managerial skills, including efficient use of agricultural inputs. Thus, ensuring improved educational attainment of Irish potato farmers would be very beneficial in improving efficiency in Irish production.

Family size: **T**he number of persons living in the family was hypothesized to reduce technical inefficiency. However, the result in Table 10 shows that the coefficient of family size is positive and significant at 10%. The result is unexpected that family size is found to determine efficiency negatively. This may be because that household with large family members may not be able to use appropriate input combinations due to shortage of cash. According to the other studies Shumet (2012) and Orewa and Izekor, (2012) among others have found negative and significant result of inefficiency that family size determines efficiency positively while Mekdes (2011) and Endalkachew (2012) found that family size determines efficiency level significantly and negatively.

Off-farm: it refers to the opportunity employed that the farm household head had to work outside their own farm operations. A number of studies conducted revealed that off -farm activities have a systematic effect on the technical efficiency of the farmers. This is because farmers may allocate more of their time to off-farm activities and thus may lag in agricultural activities. In the other hand, incomes from off-farm activities may be used as extra cash to buy agricultural inputs and can also improve risk management capacity of farmers. Off -farm activity can directly link with the timely availability of family labor for own farm operations. That means, the time at which some portion of the family labor is diverted towards off -farm works can delay farm activities. Hence, the negative relationship between off-farm activities and technical efficiency might imply that there is an overlapping between both activities.

Hence, shifting some labor to other off-farm activities can have a positive contribution for widening the gap between the observed and the potential attainable level of output of potato in the study area. It was hypothesized that off-farm occupation has a negative effect to technical efficiency of the farmer since potato farming in general needs a day to day close supervision of the operator or his representative family members. According to Table 9, the coefficients of the variable entered into the technical inefficiency effect model indicated that the variable affects the level of technical efficiency in potato production negatively and significantly at 1%. In other words, those farmers engaged in some off-farm activities are technically less efficient relative to those who were not engaged in activities other than their farm operation. This can further be explained in such a way that either farmers devote less time for their actual farm operation if they have other alternative works from which they can get immediate cash income or farm operations are becoming delayed. This shows the competitive nature of the off -farm operation with the actual farm activities in terms of labor as well as time allocation.

Farm size: The coefficient of farm size was positive and statistically significant at 1 % level indicating a direct relationship between farm size and technical efficiency. It is measured as total land cultivated by the farmer. That means total area cultivated under household farmer has affected technical inefficiency level positively and significantly. This shows that a farmer operating on large area is less efficient than farmers with small land holding size. This might be because an existence of increased in area cultivated might entail that the farmer might not be able to carry out important crop husbandry practices that need to be done on time, given his limited access to resources. Hence, the nature of potato farming needs close supervision and activity like disease and pest management practice, timely watering, and right time harvesting would require the full involvement of the operator farmer that may be tide-up if he has holding large size of land. As a result, with increase farm holding size the technical efficiency of the farmer might decrease. According to different authority (Aynalem, *et al.,* 2005; Mekdes, *et al.,* 2011) finding also their results show the same.

Improved seed: There are various varieties of improved seed in the area for potato production. Some of the varieties are Gudane, Jalane and Balete were local improved potato varieties and it distributed form Holeta agricultural research center. The data obtained from the farmer improved seed had a negative coefficient of -0.916 and was significant at 5%. A comparison between farmers that used improved seed and those who used local seed suggested that farmers who used improved seed likely to have higher technical efficiency than those who used local seed, holding all other things constant. This is because improved seed has been tailored to enable farmers reap higher yields, resist some crop diseases and pests, and serves as a pathway to achieve quality traits such as higher micronutrient content, dry matter content, sugar content and taste that do not necessarily contribute towards improving yields but are essential for achieving other goals, such as consumer acceptance and improved diet quality Low *et al* (2009). The indication that technical efficiency and use of improved seed were positively correlated was in consonance with prior expectation and consistent with findings by Ahmad *et al., (*2014) and Chiona *et al*.,(2014).

Conclusion
From the result age is one of the important aspects to determine farmers' experience of management of their agricultural production. The survey data showed that the mean age of the sample household heads were 42 years. The education levels of selected potato farmers for this study ranged from zero (illiterate) to diploma level. From the total sample farmers, about 52.9% of them have attended formal level of schooling. From respondents involved in potato production the majorities (83.8 %) were male and 16.7 % were females. There are various factors explain gender difference engaged in potato production. For example, women in rural areas are mostly involved in domestic activities such as collecting water and firewood, caring children at home; preparing food for family etc. The mean total land holding of total sample household in the study area was 3.12 hectare with standard deviation of 1.99 hectare. Result of the frontier production function indicates that all conventional input variables were found to be binding in the potato production, meaning that an increase in one of inputs will enhance production keeping everything constant. Generally, all significant input variables were found to affect output. The estimation of the frontier model with inefficiency variables shows that the mean technical efficiency of farmers in the production is 0.867. This implies that it is possible to increase potato yield up to 13.3 percent. The estimated stochastic production frontier model indicates that amounts of seed, labor, labor of oxen and amount of chemical used and are significant determinants of production level. The positive coefficients of these parameters indicate that increased use of these inputs will increase the production level to a greater extent. Hence given these inputs are used to their maximum potential, introduction and dissemination of these inputs will enhance the production level of potato in the area. The production efficiency of potato farming was determined by gender, age, family size, education, off farm activity, farm size, and improved seed.

Recommendations
Based on the results of descriptive and econometric analysis, the study has got some recommendations. The technical efficiency of the farmers can be increased through better uses of the available resources especially: seed, land, oxen power, and pesticides. 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. The technical efficiency of the sample farmers was highly influenced by the demographic variable age. This implies that age and education levels were influence to use inputs in efficiently for potato production. Hence, age and education of farmers were an important factor in improving the efficiency of farms. The possible recommendation drawn from this result include creating forum for experience sharing with experienced farmers and provision of trainings on potato production and improved practices for younger farmers.

Negative effect of off-farm activity of farmers also enabled us to recommend the creation of financial opportunities through credit facilities. Credit could replace off-farm income as a source of fund for the farm and improve the efficiency of the farmers. Therefore, efforts towards establishing and strengthening of micro finance institutions and agricultural cooperatives to assist farmers in terms of financial support thorough credit are decisive.
The results show that use of improved seed improves technical efficiency. Finally, the study recommends further empirical work to be conducted on the effects on technical efficiency of potato.

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