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Technical efficiency and profitability of potato production by smallholder farmers: The case of Dinsho District, Bale Zone of Ethiopia

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The study aimed to analyze the technical efficiency and profitability of potato production by smallholder farmers in Dinsho District of Bale Zone of Ethiopia. Cross sectional data collected in 2015/16 production year from 147 surveyed households was utilized in achieving these objectives. Non-parametric net crop revenue analysis and Cobb-Douglas stochastic frontier approach were used to analyze enterprise profitability and to estimate the technical efficiency levels in potato production, respectively. The result of net crop revenue analysis indicated that potato production was profitable wherein the producers had earned net return of about 11,740.9 ETB (Ethiopian Birr). Further analysis of the gross and net income data showed wide variation of the results between harvesting seasons and off-peak season. The test result of Cobb-Douglas stochastic frontier indicated that the relative deviation from the frontier due to inefficiency was 94%. The mean technical efficiency of farmers in the production of potato was 0.89. The estimated stochastic production frontier model indicated that area of the plots, amounts of NPS fertilizers, amount of seed and labor in man-days were positive and significant determinants of production level. The estimated SPF model together with the inefficiency parameters showed that age, age square, education, land ownership status, extension contact, number of plots (fragmentation), household size and livestock significantly determined efficiency level of farmers in potato production in the study area. To this end, the attention of policy makers to improve agricultural production should not revolve solely around the introduction and dissemination of new technology to increase yield, but also more attention should be given to improve the existing level of efficiency.

Key words: Ethiopia, potato, profitability, stochastic production frontier model, technical efficiency.

INTRODUCTION

Agriculture is the most significant contributor to Ethiopia's national economy (World Bank, 2006). It employs about 85% of the total labor force (MoFED, 2013). Moreover, the share of agriculture to total export proceeds increased consistently from about 63% in 2002/2003 to 82% in 2008/2009, though it slightly declined to 71% in

2010/2011.

In contrast to this, the share of non-agricultural goods (merchandise goods and gold) was, by and large, constant during the same period with a slight increase since 2008/9 (EEA, 2013).

Agriculture accounted for 43% of GDP in 2012/13 fiscal year (MoFED, 2013). The World Bank (2006) noted that "The dominant agricultural system in Ethiopia is smallholder production under rain-fed conditions." The same report shows that there is strong positive correlation between growth in GDP as well as per capita GDP and agriculture and crop production which further demonstrates the importance of agriculture to the Ethiopian national economy. All these factors direct the country's development policies, strategies and objectives towards improving the agricultural sector and the livelihood of rural population. In this context, various efforts were made by the preceding regimes. However, the sector could not produce enough food to support the rapidly increasing population. Consequently, both chronic and transitory food insecurity problems continue at the household level in Ethiopia (FAO/WFP, 2012).

According to the Global Hunger Index (2013), levels of hunger are still "alarming" or "extremely alarming" in 19 countries, including Ethiopia, meaning food security is an urgent issue. Potato (*Solanum tuberosum* L.) has great potential when it comes to food security (UNDP, 2014). Thus, among the crops that have increasingly gained importance to overcome food insecurity problems in Ethiopia is potato. The potential of potato for food security is increasingly being noticed as witnessed by growing interest of private investors and policy makers in this crop. In recent years, potato production has expanded because of the availability of improved technologies, expansion of irrigation structure and increasing market value (EIAR and ARARI, 2013). 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). Furthermore, as cited in EIAR and ARARI (2013), for Sub-Saharan Africa (SSA), Scott et al. (2000) projected a 250% increase in demand for potato between 1993 and 2020, with an annual growth of 3.1%. The growth in area under production is estimated at 1.25% a year, the rest of the increase being achieved through predicted growth in productivity. Increased potato productivity will play a buffer role to the increasing food prices; thus, enhance household income in the project countries with a spill over to other countries in SSA.

In the study area also, there is a problem of food insecurity. According to the Dinsho District's Agricultural Office data (2015), more than 8,000 people have received relief food assistance only for the second half of 2015 fiscal year. In this regard, production of potato has great food security 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 (Dinsho District Agricultural Office (DDAO), 2014). However, given the mounting pressure on land, sustaining higher rates of growth in agriculture production requires substantial improvements in factor productivity. Consequently, transformation in the structure of production (mostly subsistence-based) to more commercially-oriented production will be key in sustaining growth. In an economy where resources are scarce and opportunities for new technologies are limited, efficiency studies will be able to show that it is possible to raise the productivity by improving efficiency without raising the resource base or developing new technology (Tijani, 2006). Estimate of the extent of efficiency also help in deciding whether to improve efficiency or to develop new technology to raise farm productivity. Consequently, this study was undertaken in Dinsho District of Bale Zone of Ethiopia to assess profitability and technical efficiency of potato production by:

1. Measuring the existing level of technical efficiency in the production of potato in the Dinsho District.
2. Identifying the determinants of technical efficiency of potato production in the study area and;
3. Determining the profitability of potato production in the study area.

METHODOLOGY

Description of the study area

Dinsho District (7°10′ -7.167°N and 39°55′- 39.917°E; DDAO, 2014) is one of the 18 Districts found in Bale Zone. The administrative town of the District is Dinsho, located 400 km from Addis Ababa and 30 km from Bale Zone's administrative town of Robe town. There are 9 rural kebeles and one-town dwellers association in Dinsho District. According to the 2007 National Census, the total population of Dinsho District was 68,675 (48.35% males and 51.65% females); 11.38% of the populations were urban dwellers (CSA, 2007). The people's livelihood strategies mainly depend on mixed farming. The majority (85.98%) of the inhabitants were Muslims, while 13.65% were Ethiopian Orthodox Christians (DDAO, 2014). The altitude of the District is estimated at 1,500 m and 3,644 m above sea level. Two agro-climatic zones cover the

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Table 1. Distribution of sampled kebeles and households.

Total Number of kebeles	Sampled kebeles	Household per kebeles	Sampled households
9	Abbakara	1094	65
	Hoomma	431	26
	Zaalloo Abaaboo	950	56
	3	2475	147

District, namely 'Dega[1]' (95%) and 'Woinadega[2]' (5%) and are indicative of the District's potential of being potato production area. Mean annual rainfall ranges from approximately 3,400 mm to 4,500 mm with mean annual temperatures varying from -3°C to 24°C (DDAO, 2014).

Sample size and sampling techniques

Sample size determination

Sample size was calculated according to Yamane (1967):

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

Where *n* is the sample size, *N* is the population size, and *e* is the level of precision. In order to determine the required sample size (total number of households) for this study following Yamane (1967), at 95% confidence level, 0.5 degree of variability and 8% level of precision:

$$n = \frac{2475}{1 + 2475(0.08)^2} = \frac{2475}{16.84} = 146.95 \approx 147$$ (Total number of farm households)

Sampling techniques

Since farm household heads were responsible for day-to-day farming activities, they were taken as the basic sample unit in this study. Potato was produced by almost all households in the study area. However, to draw the required sample for this study, first complete list of the household data including the socioeconomic characteristics of the households were obtained from the district's agricultural office after which producers and non-producers were differentiated. After that only those households producing potato during the survey period (2015/2016) were included in the sample selection. The distribution of the sampled kebeles and households drawn using random sampling techniques and probability proportional to size of each kebele's population are shown in Table 1.

Sources and method of data collection

This study mainly relied upon primary data sources that were collected from a semi-structured questionnaire given to sampled respondents by trained enumerators. Key informant interview was used to support the information collected though questionnaire. Relevant secondary data sources were also assessed to supplement the primary data.

Methods of data analysis

Non-parametric analysis

Net crop revenue analysis was used to provide descriptive evidence of enterprise profitability through the following steps:

GFB = OPH *AVP (2)

Where: *GFB* is gross field benefits, *OPH* is output harvested, and *AVP* is the average selling price. Based on the GFB value calculated in equation (2), net crop revenue was calculated as:

NR = GFB -TVC (3)

Where: *NR* is net returns, and *TVC* is total variable cost.

Finally from NR, a return to factors used in the production of potatoes was calculated by using return to variable cost (RVC) as follows:

RVC= NR/TVC (4)

Parametric method

Crop production in general in the study area and potato production in particular are likely to be affected by random weather events and pest infestation. Additionally, measurement errors are likely to be high. Thus, given the inherent stochastic nature of crop production (Coelli et al., 2005), the stochastic frontier production function approach appears to be an appropriate method for estimating technical efficiency in agriculture of potato production in Dinsho District. However, the difficulty of specifying in advance an appropriate functional form for the data at hand is one shortcoming of the stochastic frontier model. In stochastic frontier model, the two most important functional forms widely utilized were Cobb-Douglas and Translog production functions. Both functional forms have their own strengths (Haileselassie, 2005) and short- comings (Haileselassie, 2005). Therefore a generalized likelihood ratio test was used to determine an appropriate functional form to fit the data used in the present study. The Generalized log-likelihood ratio (LR) was calculated based on the hypothesis that all interaction terms were zero including the square specification (in the translog functional form):

LR = −2 [L (Cd) − L (Tl)] (5)

Where: LR = Generalized log-likelihood ratio

[1] Commonly used Ethiopian term for areas of altitude above 2400 meters
[2] Commonly used Ethiopian term for areas of altitude between 1800 and 2400 meters

L (Cd) = Log-likelihood value of Cobb-Douglas
L (Tl) = Log-likelihood value of translog

Following Coelli et al. (2005), the farm's technology is represented by a stochastic production frontier as follows:

$$Y_i = f(X_i; \beta) + \epsilon_i: i = 1, 2, 3...n. \quad (6)$$

Where, Y_i represents output of potato for the i^{th} farmer in quintals/ha, $f(X; ß)$ is a suitable production function, X_i are the inputs used in production of potato in units/ha, βi are the coefficients to be estimated, ϵ_i is a composite error term defined as:

$$\epsilon i = v_i - u_i \quad (7)$$

Where: v_i represents random errors assumed to be distributed IID N $(0, \delta_v^2)$ and capture events beyond the control of farmers. u_i (where $u_i \geq 0$; N (μ, δ_u^2)) capture technical inefficiency effects in the production of potato. According to Battese and Coelli (1995), the influence of the inefficiency component can be measured by:

$$\gamma = \frac{\delta_u^2}{\delta_s^2} = \frac{\delta_u^2}{\delta_v^2 + \delta_u^2} \quad (8)$$

Where:
γ - is the parameter which 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.
δ_u^2 - is the variance parameter that denotes deviation from the frontier due to inefficiency;
δ_v^2 -is the variance parameter that denotes deviation from the frontier due to noise;
δ_s^2 -is the variance parameter that denotes the total deviation from the frontier.

The empirical model of the Cobb-Douglas production function for potato production in its logarithmic form is specified as follows:

$$\ln(y) = \beta_0 + \sum \beta_i \ln x_i + v_i - u_i \quad (9)$$

Where:-
y - is the total output of potato obtained during the survey period in quintal,
ln - natural logarithm,
X_1 (Area) – is the total area of land in hectare allocated for potato crop by the i^{th} farmer.
X_2 (Oxen power) - the total number of oxen days used by the i^{th} farmer[3]
X_3 (Amount of seed) - is the amount of seed used in kg,
X_4 (Amount of NPS[4] fertilizer used) - amount of NPS chemical fertilizer used in kg,
X_5 (Amount of Urea used) . amount of UREA chemical fertilizer used in kg,
X_6 (Labour) - is the total amount of labour in man-days equivalent,
β_1 - parameters to be estimated,

The inefficiency model based on Battese and Coelli (1995) was specified as follows:
$u_i = g(Z_i: \sigma i)$

Where,
u_i -Technical inefficiency error term
δ_i - Vectors of coefficients to be estimated
Z_i -Vectors of explanatory variables defined in the next section.

Given the specification of the stochastic frontier production function defined in equation 10, the technical efficiency of the i^{th} farmer is:

$$TE_i = exp(-u_i) \quad (11)$$

The ML estimates of technical efficiency effects of the model were estimated using a software package FRONTIER VERSION 4.1 (Coelli, 1996) specifically designed for the estimation of efficiency.

Definition of efficiency variables and hypothesis

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

Age: 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. However, as the farmer gets older his managerial ability is expected to decrease. To see the diminishing effect of age on efficiency a quadratic functional form is specified in the inefficiency effects model. Hence, the age and the age square were hypothesized to have positive and negative effect on technical efficiency of potato production, respectively.

Education: Formal education commonly measured in years of schooling of the farmer has received most of the attention in the frontier efficiency literature. 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 measured in years of schooling was hypothesized to determine TE positively. The results of different researchers in different area showed the same result confirming this hypothesis (Dolisca and jolly, 2008; Bonabana-Wabbi et al., 2012; Jwanya et al., 2014).

Land ownership: this is a dummy variable taking a value of 1 if the household head was cultivating owned and/or hired land and 0 if it was sharecropped land. Land ownership is one of the variables that were 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; they tend to give priority to their own land in all aspects. They may do so because outputs that will be obtained from sharecropped lands are eventually shared between the owner and the operator farmer. Therefore, farmers who were managing either their own land or hired land were expected to be more efficient than those farmers who were managing sharecropped land.

Farm size: Measured in terms of landholding size in hectares was

[3] One oxen-day is equivalent to plowing with a pair of oxen for 8 hours.
[4] NPS fertilizer is new fertilizer released to the area and used instead of DAP.

expected to determine the efficiency differential of farmers in the study area. As farmers holding large farm size have the capacity to use compatible technologies that could increase the efficiency of the farmer, relatively farmers holding large farm size in the study area were expected to be more efficient.

Extension contact: It is the frequency of contact between extension workers and potato producer. It influences the growth of agricultural by assisting the dissemination of new technologies to farmers as a way of increasing agricultural productivity. Therefore, farmers who have had more extension contact were expected to be more efficient than others. Abdullah et al. (2006) obtained the result where extension contact was the significant variable influencing the efficiency level of producers in the study area.

Household size: It measured the size of households in terms of adult equivalent. In the rural areas, household members are an important source of labour supply used in production of crops. In addition, farmer who has large household size would manage crop plots on time. Thus, household size was hypothesized to determine efficiency level positively.

Sex: this is a 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 as more efficient than males. However, according to 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: Fragmented lands are 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 determine efficiency negatively. Fekadu (2004) obtained the same result.

Livestock: It refers to total number of livestock owned by the farm households measured in tropical livestock units (TLU). Livestock supplements the production of crops in various ways. The income obtained from livestock serves to invest on crop production especially to purchase inputs. Livestock manure could also be used to improve soil fertility. It is also the main sources of animal labour in crop production. Thus, livestock was hypothesized to determine efficiency positively. In line with this hypothesis, Temesgen and Ayalneh (2005) obtained similar result.

Irrigation: this is a definition of dummy needed; It refers to the access of the farmers to irrigation scheme used to increase the production of potato in the study area. Farmers using irrigation are expected to be more efficient than those farmers producing without using irrigation. Thus, it is a dummy variable hypothesized to affect the efficiency level of farmers positively. Huynh and Yabe (2011) confirmed this hypothesis.

Credit use: It refers to the amount of money borrowed from different credit sources. Credit use for the purpose of purchase of agricultural inputs like improved seed, chemical fertilizers, etc. are expected to improve efficiency level of the farmers. Consequently, households who are getting the amount of credit they required were expected to be more efficient than others. Dolisca and Jolly (2008) reported the amount of credit received is positively related with efficiency. Thus, following this finding the amount of credit received was hypothesized to be positively related with efficiency.

Income from off/non-farm activities: It refers to the sum total of earnings generated in the survey year from activities outside farming like retail trading business, casual work on wage basis, etc. When income earned from crop production and sales of livestock and livestock products are inadequate, households often look for other income sources other than agriculture to finance their farming activities. Consequently, income earned from such activities enables households to increase their efficiency level. Jwanya et al. (2014) reported households earning higher off/non-farm income were more efficient. Therefore, in this study, in line with this finding, household who were earning higher off/non-farm income were expected to be more efficient.

RESULTS AND DISCUSSION

Profitability analysis

Enterprise cost analysis

The summary of total variable cost of potato production consisting of cost of labor (both hired and family labor), cost of fertilizer, cost of chemicals, cost of seeds and cost of oxen labor are presented in Table 2. The opportunity costs were used to calculate the out-of-pocket expenses of some inputs. According to results, cost of seed, oxen, labor and fertilizers were the most important input which contributed significantly to the total variable cost of potato production. In contrast, the share of chemicals from the total cost of production was low. This was attributed to the fact that major activities in production of potato including land preparation, weeding and harvesting were undertaken by utilizing either more labor force or oxen labor, or both. Application of herbicide and pesticide was low and when weeding was necessary, it was mostly done by hand.

Profitability assessment

Results presented in Table 3 show that the net return that the farmers obtained from production of potato was about ETB 11,740.9 per year which implies that potato producers were making a profit at an average price. Returns to variable cost was about ETB 1.51 per year which implies that for each Birr invested in variable input used in production of potato the return would be ETB 1.5 per year.

Seasonal effect

On average, the potato price was ETB 294.28/quintal. The peak potato-harvesting season in the district occurs

Table 2. Enterprise cost analysis.

Input category	Average costs	Share from total variable cost (%)
Family labor	1,757	22.46
Hired labor	83.5	1.07
Total labor	1,840.51	23.53
NPS fertilizer	1,764.54	22.56
Urea	0	0
Chemicals	170.15	2.18
Seed	2,163.44	27.66
Oxen labor	1,883.33	24.08
Total variable costs	5,274.017	100

Table 3. Gross margin analysis of potato production.

Variables	Potato
Average area planted (in ha)	0.513
Average output	66.81
Gross income at average prices	19,661.01
Total variable costs	7,821.97
Net returns	11,839.04
Returns to variable costs	1.51

in October and December. Price analysis revealed a wide seasonal variation in potato prices between harvest and off-peak periods. Price margins of about ETB 500/quintal was observed. As expected, prices were highest during the off-peak periods and dropped during the peak harvesting periods. Potato prices varied from a low of ETB 100/quintal to ETB 650/quintals, corresponding to the peak harvest period and the off-peak seasons, respectively (Figure 1). In addition, there was also a wide variation in gross income and net income earned by surveyed households across seasons. According to results presented in Table 4, gross incomes and net returns were highest during the off-peak seasons and lowest at harvesting. These results highlight the importance of delaying harvesting seasons. In this regard, some farmers in this study area can delay the potato harvesting season by leaving potato products underground and planting other short period products on top for a given period.

Econometric results

Tests of hypothesis

In the first case, the functional form that better fit to the data at hand was tested by using likelihood ratio (LR). Results presented in Table 5 show that the computed LR value was 20.74 and is lower than the upper 5% critical value of the $\chi 2$ at 15d.f (It is the number of interaction terms and square specifications in the translog restricted to be zero in estimating the Cobb-Douglas functional form). This shows that the coefficients of the interaction terms and the square specifications of the input variables under the Translog specifications are not different from zero. As a result, the Cobb-Douglas functional form specified in the methodology was obtained as the best fits for the data. In the second case, the existence of inefficiency component of the total error term of the stochastic frontier specification ($\gamma = 0$ or $\gamma > 0$) was tested using LR statistics. The higher LR value revealed the existence of inefficiency or one-sided error component in the model. According to the results presented in Table 5, the null hypothesis stating that all coefficient of the inefficiency effect model are simultaneously equal to zero was rejected in favor of the alternative hypothesis which stated that all explanatory variables associated with inefficiency effects model were simultaneously different from zero.

The discrepancy ratio (γ) calculated from the maximum likelihood estimation of the full frontier model was 0.940. The results indicate that 94 percent of the variability in potato output in the study area in the survey year was due to technical inefficiency effect, while the remaining 6 percent variation in output was due to random noise effect.

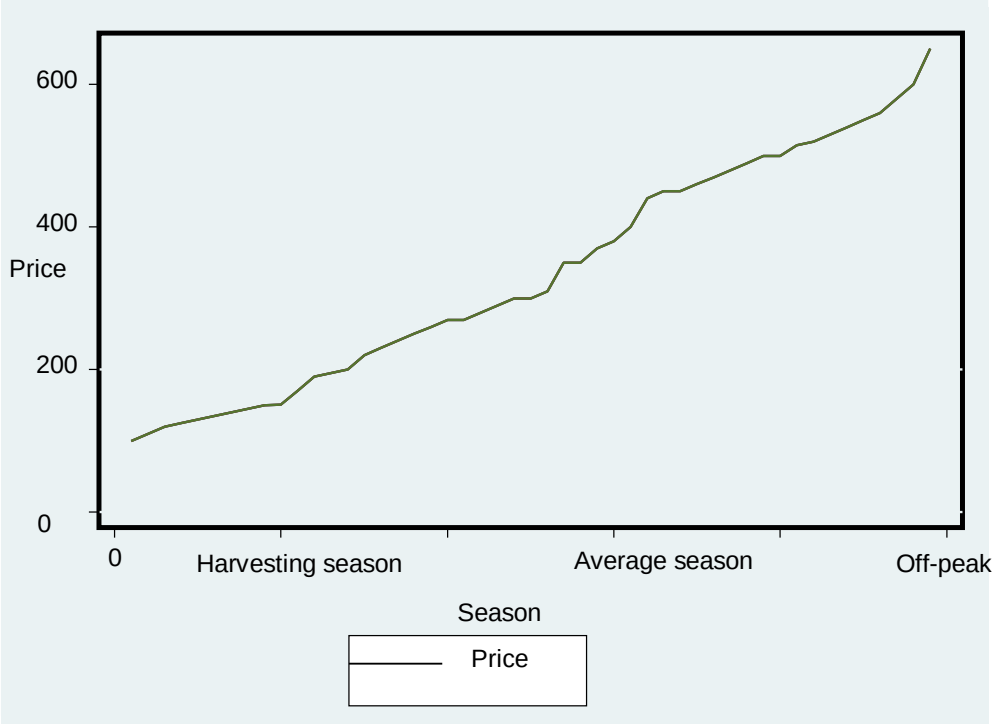

Figure 11. Seasonal price variation of potato

Table 4. Gross income analysis across seasons.

Period	Average gross income	Average net return
Harvesting season	9,948.46	2,126.49
Average season	17,438.54	9,616.57
Off peak season	31,596.03	23,774.06

Table 5. Generalized likelihood-ratio test of hypotheses for parameters of SPF.

Null hypothesis	LR value	Critical value	Decision
H_o: $\beta_{ij=0}$	20.74	25	Accept the null
H_o: $\gamma = 0$	38.37	3.841	Reject the null
H_o: $\delta_1 = \delta_2 = \delta_3 = ... = \delta_{12} = 0$	58.133	18.31	Reject the null

Parameter estimates of SPF model

In the estimation of the Cobb-Douglas production frontier, one stage estimation procedure was utilized in which both the determinants of the production frontier and inefficiency effect were included in the model. In this estimation process two variables including urea and irrigation were hypothesized as the important determinants of production frontier and inefficiency effects, respectively. However, these variables were dropped from the model because they were not used in the potato production under analysis. Farmer in the study area did not include urea as part of their potato production. Irrigation was used for other crops other than

Table 6. Maximum-likelihood estimates of SPF model

Variables	Cobb-Douglas		
	Coefficient	Standard error	t-ratio
Constant[a]	2.14***	0.34	6.30
Area	0.30 ***	0.11	2.70
Oxen	0.16	0.10	1.54
Seed	0.30***	0.06	5.34
NPS fertilizer	0.08 *	0.05	1.82
Labor (MD)	0.32***	0.32	3.42
Sigma-squared	0.360***	0.04	6.023
Gamma	0.940***	0.07	12.91
Log likelihood function	58.29		

a, natural log values of the constant term
***,**, *significant at 1%, 5% and 10% level of significance

potato. Results presented in Table 6 show that area of the plot, seed, NPS fertilizer and labor were positive and significant input variables that affect potato production in the area.

Estimation of farm level technical efficiency

Given the functional form used, the results presented in Table 7 show that the mean efficiency level of the sampled farmers was 89%. This value shows that, on average, farmers can increase their current output level by 11% without increasing the existing levels of inputs. Conversely, farmers on average could decrease inputs (area, NPs fertilizer, and seed) by 11% to get the output they are currently getting if they use inputs efficiently. Moreover, according to results presented in Table 8, in the study area there was significant variation in efficiency level among the sampled farmers. However, given these variation in the efficiency level of the sampled farmers, most of the surveyed households achieved an efficiency level greater than their mean level. This indicates that, in the long run there is a need for introducing of new technology besides improving the current efficiency levels of the farmers to increase the output level of potato in the study area.

Determinants of technical efficiency

One-stage estimation technique was used in this study. The results of the estimation were presented in Table 9. In the next section, the effect of significant inefficiency variables on the technical efficiency of the farmers in the study area would be discussed by decomposing them into three major groups.

Table 7. Estimated technical efficiencies of the sampled farmers

Statistics	TE estimates
Mean	0.89
Standard deviation	0.09
Minimum	0.51
Maximum	0.98

Table 8. Distribution of the sampled farmers by technical efficiency levels

TE level	Percent
0.5-0.6	1.36
0.6-0.7	6.12
0.7-0.8	7.48
0.8-0.9	22.45
0.9-1	62.59

Demographic factors

Age of the household head: This variable was found to be a significant variable in explaining the variation in technical efficiency among farmers considered. These indicate that older age positively affects technical efficiency in potato production, likely because older farmers tend to be more experienced in various timing-related aspects of farm management until they reach

Table 9. Maximum-likelihood estimates of the inefficiency variables.

Variables	Coefficients	Standard error	t-ratio
Constant	3.392**	0.57	5.951
Age	-0.132**	0.053	-2.486
Age square	0.002*	0.001	1.932
Education	-0.185*	0.103	-1.797
Landownership	-3.833**	1.202	-3.190
Farm size	-0.059	0.083	-0.706
Extension contact	-0.552**	0.225	-2.454
Household size	0.270**	0.104	2.581
Sex	-0.718	0.543	-1.322
Fragmentation	-0.266**	0.104	-2.549
Livestock	-0.205*	0.101	-2.025
Credit use	0.0003	0.001	0.505
Income from off/non-farm activities	0.000	0.000	0.000

***, **, * significant at 1, 5 and 10% significance level respectively
Source: Own computation (2016).

certain age level. After that age level, experiences may saturate and the marginal effect on improvement on technical efficiency might decrease. Our finding is consistent with what other researchers have found (Fekadu, 2004; Kinde, 2005; Getachew and Bamlak, 2011), that farm management practices improve over the years as farmers become more experienced. Moreover; farmers may accumulate good command of resources such as labor, oxen and farm tools thus enhancing production efficiency: more farm resources, faster inputs application in crop production and improved farm efficiency (Getachew and Bamlak, 2011).

Education: Statistically, educational level of the household head significantly affects the famer's efficiency level. That is, farmers with more years of schooling were found more technically efficient than their counterparts. Reason being that, educated farmers may have relatively adequate knowledge to apply improved methods to agricultural activities and, consequently, be more technically efficient. This result agrees with the empirical findings of different studies (Getachew and Bamlak, 2011; Huynh and Yabe, 2011).

Household size: Contrary to our expectation, the results showed that larger household size negatively affects efficiency in potato production (coefficient = 0.270, p≤0.05). This result is consistent with the finding of Ani et al. (2013) and Fekadu (2004).

Resource endowments factors

Landownership: The result shows that ownership is positively significant in determining the efficiency level of farmers in producing potato (coefficient = -3.833, p≤0.05). That is, farmers are more efficient in managing their own land or hired land than farmers who manage sharecropped land. This is because farmers tend to prioritize their own land in all aspects. Fekadu (2004) also found similar results in his empirical study.

Fragmentation: Contrary to expectation, number of plots positively affected the technical efficiency level of the farmers in the study area. Farmers who have large number of plots in different areas were more efficient than farmers who had large number of plots in the same area. This is because farmers who were cultivating their crops in different plots are not equally exposed to natural hazards such as frosts which are the most common threats to crops in the area. In other words, fragmentation is one strategy that farmers have to avert hazards to crops. This has an important policy implication in that increasing the number of plots would improve efficiency levels of farmers. The result of this study agrees with those of Kinde (2005) and Getachew and Bamlak (2011). The authors emphasized that farmers may benefit from fragmented plots since in different plots when strategically distributed may reduce the risks that weather variation pose to crops.

Livestock: Livestock supplements the production of crops in various ways. For example, the income obtained from selling livestock can be invested in crop production, especially to purchase fertilizer. Livestock manure could also be used to improve soil fertility. Livestock is also the main sources of animal labor in crop production.

Consequently, the results showed that farmer who have more livestock in TLU than their counterpart are more efficient (coefficient = 0.205, $p \leq 0.1$). Our result contradicts Fekadu (2004) who reasoned that farmers who held higher livestock may give attention to livestock production; hence, they may not be as efficient in crop production. However, in the study area where off/non-farm activities are meager and use of credit was less, livestock are an important additional source of income to farmers and help assess inputs of production.

Institutional factors

Extension contact: Farmers with more number of extension contacts were found more efficient than others. This implies that policies should include a greater intervention by extension workers as an important tool to promote more efficient technical support to farmers in the study area. Fekadu (2004), Haileselassie (2005) and Getachew and Bamlak (2011) found similar results that emphasized the paramount importance of increasing the frequency of development agent visits to improve the technical efficiency levels among farmers.

CONCLUSION AND RECOMMENDATIONS

Apart from difficulties in accurately measuring efficiency levels based on farmers' responses, the findings of this study revealed that there is a considerable variability in the technical efficiency of farmers in the production of potato in the study area. Therefore, to improve technical efficiency levels of farmers in the study area, some measures should be considered. First, sharing the experience of older farmers with those of different age groups could improve the level of efficiency at all levels, especially among youngsters. Incidentally, extension programs can intervene by arranging ways for the experience sharing. Simultaneously, there should be an intervention by governmental and non-governmental organizations to help older farmers by designing farm implements which are labor saving and can easily be handled. Financial constraints could be overcome by establishing and strengthening the religious practice of households by micro-finance institutions and agricultural cooperatives. Creation of off/non-farm job opportunities should also be emphasized, because, they could be a replacement for credit as a source of funds for the farmer, and consequently would improve the efficiency of farmers. More training should be provided to extension agent to improve their level of technical efficiency in helping farmers especially tailored to potato producers' conditions. In addition to strengthening the existing extension service provided to farmers, efforts should be made to provide long term training to farmers. Livestock provide plough power and additional income to households which can be converted into input to increase farm production. Consequently, livestock development packages must be introduced and promoted to increase their production and productivity. Fertilizer was the important determinants of potato production as revealed by SPF. There should be timely supply of fertilizer at a reasonable price to improve the efficiency of farmers in the production of potato and other crops. Therefore, the attention of policy makers to improve agricultural production should not revolve solely around the introduction and dissemination of new technology to increase yield, but also more attention should be given to improve the existing level of efficiency.

CONFLICT OF INTERESTS

The authors declared that there is no conflict of interest.

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