RESEARCH ARTICLE

Efficiency, Yield Gaps, and Profitability of Potato (*Solanum Tuberosum*) Production in Kombolcha District, Oromia National Regional State, Ethiopia

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Abstract

The study assessed potato production efficiency using the stochastic frontier production function. The study also used descriptive statistics to analyze the data. A sample of 120 potato farmers was selected using multistage random sampling techniques. The results showed that farmers used inputs like land, labor, seed, NPS (Nitrogen, Phosphorus, and Sulfur) and Urea fertilizers to produce a potato. On average, these farmers were not economically efficient in producing the crop. The average technical, economic and allocative efficiencies were 91%, 46% and 51%, which meant that the average inefficiency appeared 9%, 54%, and 49% respectively. The result also showed that 18.14 quintals per hectare of yields were lost due to inefficiency. Socio-economic and institutional factors determined efficiency scores. The results suggested that policymaker needs to consider these factors affecting efficiency scores.

Keywords: Efficiency, Potato production, Stochastic frontier function, Yield gaps.

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Introduction

Potato (*Solanum tuberosum*) is a major root, tuber and vegetable crop and most diverse in the world. Worldwide more than 320 million tons of potatoes are produced on 20 million hectares annually (Cromme, Prakash, *et al.* 2010). It has been recognized as one of the main crops to alleviate hunger and malnutrition in the world (Cromme, Prakash, *et al.* 2010); (Guenthner 2010). Because of its ability to provide a high yield of high-quality product per unit input than major cereal crops, potato becomes important to achieve food security of the farmers (Hirpa, Meuwissen, *et al.* 2010). In Africa, most of the production of potato is concentrated in East Africa (Cromme, Prakash, *et al.* 2010). In Ethiopia, the area under potato production was about 66,745 hectares with an average national yield of 117 quintals per hectare in the harvest year of 2013/14 (CSA, 2014). Potato has been considered as a strategic crop by the Ethiopian government to enhance food security and income generations (Emana and Nigussie 2011).

In Ethiopia, farm income is very low due to the backwardness of the sector (Tadesse 2005), and a high level of economic inefficiencies. It is generally believed that resources in the agricultural sector of the least developed countries are being utilized inefficiently. To increase crop yields, introducing high yielding varieties of crops and production efficiency are very necessary. It is widely held that efficiency is at the heart of agricultural production because farmers can expand the scope of agricultural production through the efficient use of resources. For these reasons, efficiency has remained an important subject of empirical investigation where the majority of the farmers are resource-poor (Umoh 2006). According to (Bifarin, Alimi, *et al.* 2010), efficiency is a very important factor in productivity growth, especially in developing agricultural economies where resources are scarce, and opportunities for developing and adopting better technologies are decreasing. Previous studies (Essilfie, Asiamah *et al.* 2011, Chepng'etich, Bett *et al.* 2014, Abdulrahman, Yusuf *et al.* 2015, Haque, Tabassum *et al.* 2015) tried to estimate the efficiency of one of the major crops such as wheat, rice, maize, sorghum, cocoyam and sugarcane. In reality, due to variations in choosing input variables and agroecology, it is difficult to compare the efficiency level of farmers from one area to another. Given this limitation, this study assessed the potato production efficiency of farmers in Kombolcha district, Oromia regional state, Ethiopia.

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Materiels and methods

The Study Area and Method of Data Collection

The study was conducted in Kombolcha district located

about 514 km of Addis Ababa. Three *kebeles* were purposively selected based on the predominance of potato production. Subsequently, 120 potato farmers of the district were selected randomly. The primary and secondary data was collected using face to face interview, and from published materials, respectively.

Methods of Data Analysis

The survey data was analyzed using descriptive statistics, including mean, standard deviation, percentages, and frequency distribution.

Stochastic production frontier specification

In this study, the stochastic frontier analysis was used to measure the technical efficiency of potato farmers in the study area. (Aigner, Lovell, *et al.* 1977, Meeusen and van Den Broeck 1977) Suggested a stochastic frontier model for estimating technical efficiency. The following frontier production model with a multiplicative disturbance term was used in this study to estimate technical efficiency.

$$Y_i = F(X_j;\beta)e^{\varepsilon} \quad (1)$$

Where

Y_i = output (potato) in quintal

X_j = is a vector of input quantities (land, labor, seed, NPS (Nitrogen, Phosphorus, and Sulfur) and Urea)

β = is a vector of parameter and ε is stochastic disturbance term consisting of two independent elements v *and* u *where* $\varepsilon = v - u$; v represent for random variation in output due to factors outside the farmer's control. It is assumed to be normally, independently and identically distributed as $v \sim N(0,\sigma_v^2)$. u = is nonnegative random variable assumed to account for inefficiency component of the error term.

As a stochastic frontier approach (SFA) requires prior identification of the functional form, Cobb–Douglas production function was selected for this study due to its self-duality (Xu and Jeffrey 1998). Otherwise, as argued by (Alene and Hassan 2006), due to little or no input price variation across farms in Ethiopia, any econometric estimation of a cost function is very difficult. Hence, the self-dual structure of the production and cost function of the Cobb–Douglas function provides the computational advantage in obtaining the computation of economic efficiency (EE) and allocative efficiency (AE).

Dual Cost Frontier Model

The dual cost frontier of the production function in equation (2) can be derived analytically. The general form of the dual cost frontier is presented as:

$$C = C(P, Y^*;\ \alpha) \quad (2)$$

Where C is the minimum cost; P is a vector of average prices for the production inputs; Y^* is the output adjusted for statistical noise, and α is a vector of parameters to be estimated. Following (Alene and Hassan 2006) to estimate the minimum cost frontier analytically from the production function, the solution for the minimization problem given in Equation 3 is essential.

$$\underset{x}{\text{Min}}\ C = \sum_n P_n X_n \quad (3)$$

Subject to

$$Y^* = \hat{A}\prod_n X_n \hat{\beta}_n \quad (4)$$

where $\hat{A} = \exp(\hat{\beta_0})$

P_n = input prices

$\hat{\beta}$ parameter estimates of the stochastic production function and $Y^*$is the output adjusted for statistical noise.

The following dual cost function is found by substituting the cost-minimizing input quantities into Equation 3.

$$C(Y^*,P) = HY^{*\mu}\prod_n P_n^{\alpha_n} \quad (5)$$

where

$$\alpha_n = \mu\hat{\beta}_n, \qquad \mu = (\sum_n \hat{\beta}_n)^{-1}, \qquad H = \frac{1}{\mu}(\hat{A}\prod_n \hat{\beta}_n^{\hat{\beta}_n})^{-\mu}$$

The economically efficient input vector for i^{th} farmers, X_i, was derived by applying (Shephard 1970) and substituting the average input prices and adjusted output levels into the derived system of input demand equations given by:

$$\frac{\partial C}{\partial P_n} = X_{ie}(P_i, Y_i;\ \theta)$$

where θ is a vector of estimated parameters

The observed, technical, and economical, efficient costs of production of the ith farmers are equal to $\sum P_i X_i$, $\sum P_i X_{it}$, $\sum P_i X_{ie}$ respectively. These cost measures were used to compute the technical (*TE*), allocative (*AE*) and economic (*EE*) efficiency indexes for i^{th} farmers as follows:]

$$TE_i = \frac{\sum P_i X_{it}}{\sum P_i X_i} \quad (5)$$

$$EE_i = \frac{\sum P_i X_{ie}}{\sum P_i X_i} \quad (6)$$

Following (Farrell 1957), allocative efficiency index of the ith farmer can be derived from Equations 5 and 6 as follows:

$$AE_i = \frac{EE_i}{TE_i} \quad (7)$$

Determinants of Efficiency

After estimating the technical, allocative, and economic efficiency indices, the second stage of analysis was conducted on the hypothesized factors affecting the efficiency of farmers using a two-limit Tobit. The Tobit model was adopted because estimation with OLS regression of the efficiency score would lead to a biased parameter estimate (Greene

2003). According to (Tobin 1958), the two limit Tobit model is specified as:

$$y_i^* = \beta_0 + \sum \beta_m X_m + \varepsilon_j \quad (8)$$

Where y_i^* latent variable (0-1) representing the efficiency scores of farm j.

β A vector of unknown parameters,

X_m a vector of explanatory variables m for farm j and ε_j an error terms that is independent and normally distributed with mean zero and variance σ^2.

Results and Discussion

Socio-economic characteristics of the sample farmers

On average, 89.17% and 10.83% of the respondents were male and female, respectively. The age of these sample respondents ranged from 20–67 years, with an average of about 37 years. The average age indicates that most of the sample respondents are in their active working-age group. The average family size was about 7 persons per household. On average, the educational status of the sample respondents was computed at about 6 years of schooling. The monthly income of sample households was computed at 2829.167 ETB[1]. On average, about 81.97% of the farmers were participated in off/nonfarm activities. The average farmland holding of the sampled households allocated for potato production was 32.78 hectares. Data with regard to access to extension and credit services showed that 91% and 95% of the households' had access to these services, respectively. The survey result shows that on average, 1.93 tropical livestock unit (TLU) with a minimum of 0.07 and a maximum of 4.85 was recorded per households. The respondent had about 14 years of farming experience of producing this potato crop. The findings of this study showed that farmers, on average, produced about 161.23 quintals of potato per hectare. This high yield was recorded due to the availability of credit and extension services. The summary statistics of variables used in Cobb Douglas frontier production is also given in Table 1.

1 ETB is referring to Ethiopian Birr. One Ethiopian birr is equivalent to 28.91 USD.

Profitability analysis of potato production in Kombolcha

The yield of potato was 161.23 quintal per hectare which was higher than the national average yield, 118.85 quintals per ha (CSA, 2018). The sample farmers were observed to earn profit birr of 6,653,801.00 from potato production on average (Table 2). This might be due to the district is located near to the market center such as Harar, Dire Awa, Djibouti, and Somali.

Econometric results

Cobb Douglas frontier production and dual cost function

The stochastic frontier production function estimates of potato farmers in Kombolcha district are presented in Table 3. The estimated elasticities of mean output with respect to farmland size, labor, Seed used, the quantity of NPS and Urea

Table 2: Profitability of potato cultivation in Kombolcha

Items	Value
Total Variable Cost (birr/ha)	2,980,869.00
Total cost (birr/ ha)	3,020,199.00
Yield (q/ ha)	161.23
Price (birr/q)	500
Gross return (birr/ha)	9,674,000
Gross margin (birr/ha)	6,693,131.00
Net return (birr/ha)	6,653,801
Benefit-cost ratio	3.20

Sources: own result

Table 1: Description and summary of variables used in the production function

Variables	*Measure*	*Description*	*Mean*	SD
Output	Quintal	Amount Potato produced by the household in 2018	161.23	5.87
Land	Hectare	Size of land that was allocated to potato production in 2018	0.27	0.01
Labor	Person day	Both family and hired labor used for potato production in 2018	25.27	0.45
Seed	Quintal	The quantity of potato seed used per hectare in 2018	20.05	0.66
NPS	Quintal	Amount of NPS used for Potato production per hectare in 2018	2.55	0.11
Urea	Quintal	Amount of UREA used for Potato production per hectare in 2018	2.87	0.13

Source: own data

Table 3: Estimates of the Cobb Douglas frontier production function

Variable	Coef.	SD	P>|z|
Farm land size	0.241***	0.026	0.000
Labor	0.517***	0.139	0.000
seed	0.178***	0.058	0.002
NPS	0.293***	0.044	0.000
Urea	0.098**	0.041	0.018
Cons	2.92***	0.354	0.000

*** and ** significant at 1% and 5% probability level, respectively (source: own data)

fertilizer were 0.241%, 0.517%, 0.178%, 0.293%, and 0.098%, respectively.

The dual cost frontier function is written as:

$$lnC_i = -0.73 + 0.75\ lnY_K^{i} + 0.18lnP_{land} + 0.39lnP_{labour} + 0.13lnP_{Seed} + 0.22ln_{PNPS} + 0.07lnP_{Urea}$$

Where C is the minimum cost of production of the ith farmer, Y^* refers to the total amount of potato output adjusted for any statistical noise and scale effects and P stands for input prices.

Farm-specific efficiency scores

The mean level of technical efficiency of potato growing farmers was about 91% (Table 4). The mean level of technical efficiency further indicated the level of potato output of the sample respondents could be increased by about to 9% on an average, if appropriate measures are taken to improve the level of efficiency of potato growing farmers. In other words, there is a possibility to increase the yield of potato by about 9% using the resources at their disposal in an efficient manner without introducing any other improved (external) inputs. It was observed that about 26% of the sample farmers were operating below the overall mean level of technical efficiency while about 74% of the farmers were operating at the technical efficiency level of more than 90%. This might imply that in the long run, it needs attention at the policy level to introduce other best alternative farming practices and improved technologies to enhance the production from the current level.

As shown in Table 4, the economic efficiency of potato producers was not relatively satisfactory. Although 11.67% of the farmers had economic efficiency of 50% and above, 88.33% of them had economic efficiency of less than 50%. A mean economic efficiency of 46.07%, cannot be satisfied with potato farmers. Furthermore, the average allocative efficiency of the potato producers was computed to be 51.27% which ranged between a minimum efficiency of 0.4109 and maximum efficiency of 0.8638 scores.

Yield gaps due to inefficiency

Table 5 shows the estimates of potato yield gap resulted from production inefficiency. This part is the uniqueness of this study from the previous study conducted in this country to estimate the yield gaps resulted from efficiency differentials among farmers. The mean potential yield computed to be 179.37 quintals per hectare if the average farmer had an efficiency level of 100% without the requirement of additional inputs and technology. However, the increase in potential (frontier) yield was much higher for farmers who had the lowest level of efficiencies (from 80 to 87.80 q/ha if had 100% efficiency level). Therefore, about 18.14 quintals per hectare of yield were lost due to inefficiency effects.

Determinants of efficiency scores

Table 6 presents the results of the factors influencing efficiency. The result of the two-limit Tobit model shows that family size and total farmland holding had a negative and significant effect on technical efficiency. The parameter's estimate for livestock as measured by TLU was positive and significant. This is because producers who own more livestock can apply manure adequately. This is consistent with the findings of (Jote, Feleke, *et al.* 2018). Farming experience measured by the number of years had a positive and significant relationship with efficiency. This result is consistent with the findings of (Amara, Traoré, *et al.* 1999,

Table 4: Deciles range of frequency distribution of efficiency of the farmers

	Economic Efficiency		*Technical Efficiency*		*Allocative Efficiency*	
Estimated efficiency	*Frequency*	*Percent*	*Frequency*	*Percent*	*Frequency*	*Percent*
0.31-0.40	7	5.83	-	-	-	-
0.41-0.50	100	83.33	-	-	73	60.83
0.51-0.60	13	10.83	-	-	47	39.17
0.61-0.70	-	-	2	1.67	-	-
0.71-0.80	-	-	10	8.33	-	-
0.81-0.90	-	-	24	20.00	-	-
0.91-1.0	-	-	84	70.00	-	-
Mean		46%		91%		51%
Maximum		64%		99%		86%
Minimum		37%		63%		41%

Source: Own data

Table 5: Yield gaps due to inefficiency in quintal (q)

Variable	Mean	Min	Max
Observed yield (q/ha)	161.23	80	448
Technical efficiency estimates	0.91	0.63	0.99
Computed Frontier yield (q/ha)	179.37	87.80	452.79
Computed yield loss (q/ha)	18.14	7.80	4.79

Source: own data

Table 6: Determinants of efficiency scores

	Technical Efficiency		Economic Efficiency		Allocative Efficiency	
Variables	Coef.	Std.err	Coef.	Std.err	Coef.	Std.err
Age	0.00004	0.00018	0.00043	0.00047	0.00038	0.00063
Off/nonfarm activities	0.02541***	0.00492	-0.02835**	0.01283	-0.04602***	0.01698
Family size	-0.00509**	0.00238	-0.00543	0.00620	-0.00109	0.00820
Farmland size	-0.23776***	0.02993	-0.19843**	0.07796	-0.02773	0.10321
Gender	0.00040	0.00519	0.01169	0.01360	0.01194	0.01801
Education	-0.00024	0.00041	0.00173	0.00106	0.00202	0.00141
Farming experience	0.00176***	0.00072	0.00556***	0.00188	0.00784***	0.00248
Livestock(TLU)	0.00759*	0.00444	0.02496**	0.01155	0.02725*	0.01528
Frequency of weeding	0.00517***	0.00122	-0.00308	0.00319	-0.00785*	0.00422
Extension service	0.06724***	0.00734	-0.13979***	0.02531	-0.13979***	0.02531
Credit	0.01485**	0.00720	-0.00954	0.01875	-0.02825	0.02483
Cons	0.92804***	0.03185	0.70188***	0.08293	0.75673***	0.10978

***, ** and * significant at 1% , 5% and 10%probability level, respectively (source: own data)

Abdulai and Eberlin 2001, Nyagaka, Obare, *et al.* 2010, Assa, Edriss, *et al.* 2013). Extension contact had a positive impact on technical efficiency. This implies that potato growers with increased frequency of contact with extension workers tend to be more efficient than others. However, the negative coefficient of extension contact in AE and EE may be due to the fact that the farmers never trust the government due to political reason. This is consistent with the findings of (Assa, Edriss, *et al.* 2013).

Credit had a positive and significant effect on technical at 5% level. This is because credit might help farmers to enhance efficiency by overcoming liquidity constraints for purchased inputs. This finding is consistent with the results by (Abdulai and Eberlin 2001, Assa, Edriss, *et al.* 2013).

Off/nonfarm activities had a positive and significant effect on technical at 1% level. This is because off/nonfarm activities might help farmers to generate additional income that might be used to purchase farm inputs. The frequency of weeding had a positive and significant impact on technical efficiency at 1% level. This implies that farm households with increased frequency of weeding tend to be more efficient than their counterparts. The results are consistent with the finding of (Assa, Edriss, *et al.* 2013).

Conclusion and Recommendation

This study was conducted to examine the economic efficiency of potato product. The results showed that farmland size, labor, and seed used, the quantity of NPS (Nitrogen, Phosphorus, and Sulfur) and Urea fertilizer in the stochastic frontier analysis had a positive effect. Besides, the study found that the farmers were not operating on the frontier production function. Potato yield was lost due to inefficiency effects. Appropriate training for farmers on potato production and ensuring quality seed can play an important role in minimizing the inefficiency. Agricultural policies should include measures to improve the capacity of farmers to apply the available resources more efficiently. This result further revealed that efficiency is affected by different socio-economic and institutional factors. Thus, it is useful to identify the main causes of inefficiency. To enhance the production and hence the profit of potato producers, such factors should be considered appropriately.

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