SOCIO-ECONOMIC FACTORS INFLUENCING TECHNICAL EFFICIENCY AMONG SMALLHOLDER POTATO FARMERS IN KENYA

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ABSTRACT

Potato (*Solanum tuberosum*), the second most important food crop in Kenya after maize, is a major source of carbohydrates and therefore of high nutritional value. However, its productivity is low, at an average of 9.8 metric tonnes per hectare (mt/ha), a value well below the potential of 40 mt/ha. This study sought to determine the factors that influence productivity among smallholder potato farmers in Kenya. The study was carried out in Taita-Taveta, Nyandarua, Nyeri and Elgeyo Marakwet Counties. A sample of 312 farmers were sampled through a multi-stage sampling technique. Researcher administered questionnaires were used to collect primary data. Stochastic Frontier Analysis (SFA) was utilized in computing technical efficiency scores as well as determining the factors that influence productivity among smallholder potato farmers. It was found that sex, years of education, farm income, non-farm income, group membership, access to credit, number of extension contacts, receipt of technical training, years of farming experience and land size were important factors that influenced the level of technical efficiency among smallholder potato farmers in Kenya. The study recommends that farmers with inadequate skills and experience in potato farming should get county-government aided technical training and regular extension services. Farmers organizations should also be strengthened in order to serve as an important vehicle for credit, training, and extension service which are key ingredients for increased productivity.

Keywords: Socio-economic factors; technical efficiency; smallholder farmers; potato

INTRODUCTION

With the inevitable increase in population (especially in sub-Saharan Africa), the concept of agricultural productivity has continued to gain its popularity. The countries' agricultural sectors are expected to yield more output even when a proportional increase in input is not possible. The situation in Kenya is not spared where the population trend is on an increase amidst low productivity of her agricultural systems. Productivity refers to the ratio of output to the total inputs used in farming, and is most often dependent on technical efficiency. Technical efficiency is the ability of a given level of inputs to produce maximum output at the frontier, and any deviation from these frontier outputs is considered as technical inefficiency (Coelli *et al.*, 2005). Technical efficiency (TE) entails either minimization of input use for a given level of output, or maximization of output from a given vector of inputs. With the average growth rate of 2.5 percent per year, recorded for the past 10 years (2009-2019), this trend in population demands an improvement in agriculture in order to contribute to food security. The agricultural systems in Kenya will have to feed an additional 37.4million people in the next 40 years with the projected population of 85 million by 2050 (World Bank, 2014).

Potato (*Solanum tuberosum*), the second most important food crop in Kenya after maize (CIP 2019), is a major source of carbohydrates and therefore of high nutritional value. Due to its higher productivity (about 5 times higher than that of maize per unit of land), Irish potato has the potential to feed more persons per year compared to maize. Potato matures in only 80 to 120 days compared to maize that can take up to 240 days depending on variety (Parker, 2022). Potato is a major contributor towards Kenya's national goal of food and nutrition security, poverty alleviation, job creation and industrial products (CIP, 2019). According to World Bank (2019), potato can efficiently address food insecurity and alleviate poverty in Kenya.

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Potatoes are grown in high altitude areas where maize does not perform well (Janssens *et al.*, 2013). About 70% of potatoes are grown in areas with altitude greater than 2,100 metres above sea level. At high altitudes potatoes, compared to maize, grow faster and produce more energy and protein per hectare per day. Such areas include those surrounding Mt. Kenya (such as Nyeri County), Aberdare ranges (such as Nyandarua County), Cherangani and Tugen hills (such as Elgeyo Marakwet County) and Taita hills (such as Taita Taveta County). Nyandarua County is the largest producer of Irish potatoes in Kenya.

Past studies, over one decade ago, had identified some major challenges of potato farming in Kenya, which include low productivity, over-dependence on rain-fed agriculture, erratic weather conditions due to climate change, lack of strong farmers' co-operatives for marketing, inadequate credit access, high input prices, and inaccessibility or unavailability of certified seed. Others are inadequate or inappropriate storage facilities, high post-harvest losses, pest and diseases, undeveloped marketing systems, poor produce packaging standards, lack of adequate skills, and soil degradation due to continuous production in the same piece of land (Muthoni and Nyamongo, 2010).

Climatic challenges in the country include drought, extreme temperatures, frosts, and floods. These hazards affect agricultural production negatively. Some of the adaptation strategies for potato farmers include use of improved seed varieties, changing the cropping calendar, use of indigenous information in controlling diseases, water harvesting, soil and water conservation, adoption of drought-tolerant crops, irrigation and use of greenhouses.

Many of the mitigation and adaptation measures to counteract the effects of climate change have been variously referred to as Climate-Smart-Agricultural strategies. The farmers have adopted many of the measures at diverse levels. However, potato productivity has remained low (9.8 mt/ha, which is way below the potential of 40 mt/ha). Consequently, many smallholder farmers continue experiencing food insecurity and loss of livelihoods. Technical efficiency is the ability of a given level of inputs to produce maximum output at the frontier, and any deviation from these frontier outputs is considered as technical inefficiency (Coelli *et al.*, 2005). The ability to determine the socio-economic factors influencing productivity (using technical efficiency approach) among smallholder potato farmers in Kenya constitutes an important step towards designing policies and interventions for enhancing food security and livelihoods.

MATERIALS AND METHODS

The study used correlation research design that attempts to estimate the extent to which values of selected variables are related or change in an identifiable pattern with another focal variable. In this study, technical inefficiency scores (the dependent variable) are correlated with socio-economic factors (the independent variables). The selected independent variables include: age, sex, years of education, household size, farm income, non-farm income, group membership, access to credit, number of extension contacts, receipt of technical training, years of farming experience and land size.

The study was carried out in Taita-Taveta, Nyandarua, Nyeri and Elgeyo Marakwet Counties of Kenya corresponding with the main agro-ecological zones (Zone II and III) (Infonet-Biovision (2022) classification), the major potato growing areas in Kenya. The target population of the study was all smallholder potato farmers in the selected counties who are about 145,993 (in Nyeri), 122,748 (in Nyandarua), 87,400 (in Elegeyo Marakwet) and 65,514 (in Taita Taveta) according to KNBS (2019). However, the accessible population were farming households who grew potatoes in the 2020/2021 cropping year. The sample units of the study were potato farmers comprising of both users and non-users of selected Climate Smart Agricultural Technologies and Management Practices (CSA-TMPs).
The study used a multi-stage sampling technique to obtain a representative sample. The first stage involved purposive selection of four counties owing to potato value chain importance and representation of the key agro-ecological zones where the crop is popular. In the second stage, four sub-counties were randomly selected (one per county). In the third stage, eight wards were randomly selected (two from each sub-county). The Nassiuma (2000) formula was used to prescribe a sample size of 312 representing the users and non-users of selected CSA TMPs. Proportionate allocation was used to determine the sample size from each county. Systematic random sampling was applied to select individuals who participated in the study from each of the wards. The respondents were selected at an interval of ten from the sample frame of potato farmers. A researcher administered questionnaire was used to collect primary data.

Inferential statistics through econometric modelling were used to analyze data with the aid of Stata program (Version 14.1). In this, Stochastic Frontier Analysis (SFA) was used to compute technical efficiency scores as well as determine the factors that influence productivity among smallholder potato farmers. It is acknowledged that in establishing the stochastic frontier production function, the stochastic corrected ordinary least squares (COLS) could be used. However, the COLS modelling would not be ideal since it does not accommodate the assumed distribution (half-normal) for the efficiency component. Additionally, the maximum likelihood estimation (MLE) technique as offered by SFA is more robust due to its parametric approach (as compared to non-parametric approach) and hence its ability introduces the stochastic term to represent the effect of statistical noise into the deterministic model to form a composite error term.

Estimation of the outcome variable

Potato yield (specified in 50 kg bags per acre) is a function of a set of inputs as specified in Equation (1).

$$Y_j = f(X_{ij}) \qquad (1)$$

Where Y_j is the yield (50kg bags/acre) for farmer j; X_{ij} is specific inputs used in the production of potato for farmer j. The continuous data on yield is transformed into natural logs to reduce the large deviations existing between different farmers. The transformed production function is presented as shown in Equation (2):

$$Ln(Y_j) = Ln(X_{ij}\beta_j + \mu_j) \qquad (2)$$

Where $Ln(Y_j)$ is the potato yield as specified in 50 kg bags per acre (in natural logs), X_{ij} is a vector of inputs used in producing potato yield, β_j are the parameter vectors and μ_j are independent and identically distributed (i.i.d.) error terms that follow a bivariate normal distribution.
It is acknowledged that several other studies have specified Cobb-Douglas production functions in representing the frontier analysis. However, this study considers Cobb-Douglas as a less ideal choice since it imposes a severe prior condition on the farm's technology by restricting the production elasticities to be constant and the elasticities of input substitution to unity (Nonthakot and Villano, 2008). The stochastic frontier model was first developed by Aigner *et al.* (1977) and Meeusen and van den Broeck (1977), independently, and later improved by Battese and Coelli (1995). The improvement developed a stochastic frontier production model that includes a decomposition of the error term, e_i into v_i and μ_i.

The stochastic frontier model as specified by Battese and Coelli (1995) can be presented as shown in Equation (3)

$$lnY_j = \beta_0 + \sum_n \beta_j lnX_i + e^{\ln(v_i - \mu_i)} \qquad (3)$$

Where: Y_j is the potato yield (specified in 50 kg bags per acre) from a specific farm; X_i are a set of inputs used in potato production (these include seeds, labour, capital, fertilizer, manure and agrochemicals); v_i is the usual two-sided random error; u_i is the non-negative (one-sided) technical inefficiency component of the error term; $e_i = v_i - u_i$ is the usual error term.

The noise component of the error term is assumed to be symmetric and independent and identically distributed (*iid*) with respect to u_i. Premised on the *iid* assumption, the use of OLS to estimate the above equation could yield consistent estimates of the β_n, but not of β_0, since $E(e_i) = -E(u_i) \leq 0$ (Kumbhakar *et al.*, 2001).

Just like Battese and Coelli (1995) model, the efficiency estimation depends on the assumed distribution of the one-sided error term u_i. Four possible distribution assumptions have been proposed among which the half-normal distribution of the one-sided error term has been frequently applied. The other three assumptions; exponential, truncated-normal, or gamma-normal distribution are not highly assumed. This study assumes a half-normal distribution of the one-sided error component due to its wide usage in agricultural production economics with cross-sectional data.

The translog stochastic frontier model used in the empirical analysis can be specified as follows:

$$LnY_j = \sum_{i=1}^{6} \beta_j \, lnX_{ij} + \frac{1}{2}\sum_{i=1}^{6}\sum_{j=1}^{n} \beta_j \, lnx_{ik} + v_i - u_i \qquad (4)$$

Where LnY_i denotes the natural logarithm for potato yield (specified in 50kg bags/acre) of the i^{th} farmer, X_{ik} represents inputs used by the i^{th} farmer. These include seed, labour, manure, fertilizers and agrochemicals. β is a vector of parameters to be estimated (the coefficients that are interpreted as a measure of influence of selected factors on technical inefficiency). $v_i - u_i$ is the composed error term where, $u_i \geq 0$.

According to Greene (2010), MLE makes use of the specific distribution of the disturbance term and is more efficient than COLS. The Breusch Pagan test was used to test for the presence or absence of heteroscedasticity (though this likelihood was reduced by transforming data into natural logarithms) while the variance inflation factor (VIF) was used to test for the presence or absence of multicollinearity in the model. The definition and measurement of the variables used in the stochastic frontier modelling is summarized in Table I.

RESULTS AND DISCUSSIONS

Stochastic Frontier Analysis

The maximum likelihood estimates of the parameters of the stochastic frontier model used in estimating technical efficiency are presented in Table II. All parameter estimates have the expected positive sign, where LnCapital, LnSeeds, LnPLabour, LnFertilizer, LnManure and LnAgrochem are statistically significant, meaning that these factors are important determinants of potato production (yield per acre) in the study area.

The cost of capital input was found to have a positive effect on technical efficiency as expected (*P*-value =0.000) The implication is that a rise in quantity of capital would cause

TABLE I- DEFINITION AND MEASUREMENT OF VARIABLES USED IN THE STOCHASTIC FRONTIER ANALYSIS MODEL

Variables	Description of variables	Expected sign
Dependent variable		
Ln(yield)	Natural logarithms of potato yield in 50Kg bags/acre (1 acre = 0.405 hectare)	
Inputs		
Ln (Seed)	Natural logarithms of potato seeds planted in Kg/acre	+
Ln (Labour)	Natural logarithms of labour used in man-days per acre	+
Ln (Capital)	Natural logarithms of the cost of capital in KES/acre	+
Ln (Fertilizer)	Natural logarithms of fertilizer in Kg/acre	+
Ln (Manure)	Natural logarithms of manure in Kg/acre	+
Ln (Agrochemicals)	Natural logarithms of the cost of agrochemicals in KES/acre	+
Inefficiency variables		
Age	Age of the household head in years	-/+
Sex	Sex of the household head (1=male 0=female)	+
Education (years)	Years of schooling of household head	+
Household size	Number of people in households(persons)	+/-
Farm income)	Income earned within the farm (in KES. per annum)	+/-
Non-farm income	Income earned outside the farm (in KES. per annum)	+/-
Group membership	HH membership to farming association (1=yes 0=no)	+
Input market distance	Distance from the input market in kilometers	
Access to credit	Household head receiving of credit (1=yes 0=no)	+
No. of extension contacts	Number of contacts with extension officials in the last 1 yr	+
Technical training	HH head receipt of potato farming training (1=yes 0=no)	+
Farming experience (years)	Years of experience in potato production (yrs)	
Land size	Total land holding (acres)	

an increase in output. The reason for the positive influence of capital input on potato yield could be as a result of ease of investment in climate smart agricultural practices with the help of additional capital. This agrees with the results of Tegemeo (2018) that reported a positive correlation between the extent of capital input and the output of potatoes in Kenya. These results however, disagree with IFPRI (2016) who found that access to capital input did not automatically translate into higher yields in Uganda among potato and rice farmers.

The amount of seeds planted was found to have a positive effect on technical efficiency as expected (*P*-value=0.000) This implies that seed was a key input in potato farming. Increase in quantity of seed was attributed to greater potato output. Availability of high-quality seeds is also key in potato farming. Due to limited supply of certified seed potato, productivity is low. The main challenge facing potato production in Kenya is use of poor-quality seed (potato tubers) that are highly contaminated with seed borne diseases (Okello *et al.*, 2017). An informal seed potato supply system which is made up of farm saved, seed exchanges by farmers and local markets is very common in Kenya. These results agree with Kaguongo *et al.* (2013), Mumia *et al.* (2018) and Muthoni *et al.* (2013) who in their separate studies found that the main challenge in enhancing potato productivity in Kenya is attributed to the establishment and improvement (or lack) of potato seed supply system. In their study on cost of production for Irish potatoes for the 2018 main cropping season in Kenya, Tegemeo (2018) found that labour, seed and pesticides contributed the highest to cost in that order, in Nakuru County while in Nyandarua County, seed accounted for the largest cost component followed by labour and fertilizer. According to Tegemeo (2018), the cost of seed in 2018 was very high. The high cost was influenced by the low production and high market prices since farmers mainly recycle seed from own production. According to Priegnitz *et al.* (2020), the low production of potatoes in Uganda can be attributed to the lack of a well-functioning formal seed system dealing with high-quality and healthy seed tubers.

The labour (man-days) was found to have a positive effect on technical efficiency as expected (*P*-value =0.000). This implies that labour was a key input in potato farming. Increase in quantity of labour was attributed to greater potato output. One of the main farm inputs required in potato production is labor in addition to seeds, fertilizer, pesticides, and herbicides. These findings agree with Tegemeo (2018) in their study on cost of production for Irish potatoes for the 2018 main cropping season in Kenya where they noted that the cost of labour was significant and led to lower yields. Farmers who experienced labour shortages during peak periods in the production cycle suffered from poor yields. Labour, seed and pesticides contributed the highest cost of potato production, in that order in Nakuru county while in Nyandarua, seed accounted for the largest cost component followed by labour and fertilizer.

The amount of fertilizer was found to have a positive effect on technical efficiency as expected (*P*-value=0.006). This implies that fertilizer was a key input in potato farming. Increase in quantity of fertilizer was attributed to greater potato output. This study concurs with Mwakidoshi *et al.* (2021) who found that low fertilizer use contributed to low potato productivity. According to Gitari *et al.* (2018), the optimum amount of nutrients required for potato production in achieving the required maximum yield is only through fertilizer application, which has proved to economically disadvantage small scale farmers. The application rate of fertilizer in Kenya has always been below the recommended rates, which directly results in less supply of essential nutrients required to meet the minimal crop growth performance and yield productivity (Koch *et al.,* 2020; Mugo *et al.,* 2021).. Muthoni (2016) and Nyawade *et al.* (2021) noted in their studies that small-scale farmers in Kenya habitually apply Di-ammonium phosphate (DAP) fertilizer during the planting period and rarely top-dress their crops with nitrogenous fertilizer (Mugo *et al.* 2021) hence worsening the problem of low soil pH and finally low productivity. An increase in soil acidity results in the loss of nutrients and accumulation of aluminum and manganese toxicities and reduction in potassium, calcium, phosphorus and magnesium availability in the soil (Jensen, 2010).

TABLE II- STOCHASTIC FRONTIER ANALYSIS

lnYield	Coef.	Std. Err.	z	P>z
Frontier				
LnCapital	0.598	0.028	21.630	0.000
LnSeeds	0.056	0.014	4.020	0.000
LnPLabour	0.447	0.028	16.110	0.000
LnFertilizer	0.048	0.017	2.760	0.006
LnManure	0.059	0.025	2.360	0.019
LnAgrochem	0.033	0.009	3.630	0.000
_cons	-5.392	0.222	-24.280	0.000
lnsig2v (_cons) (γ)	0.527	0.168	3.137	0.002
lnsig2u				
Age	0.235	0.290	0.810	0.418
Sex	-0.033	0.012	2.660	0.008
Education (years)	-0.232	0.092	-2.520	0.012
Household size	0.105	0.116	0.906	0.366
Socio-economic status (Inst: Farm income)	-0.171	0.027	6.287	0.000
Non-farm income	-0.131	0.034	3.858	0.000
Group membership	-0.986	0.458	2.150	0.032
Access to credit	-0.401	0.071	5.646	0.000
Number of extension contacts	-0.179	0.015	11.707	0.000
Receipt of technical training	-0.843	0.336	2.509	0.013
Farming experience (years)	-0.220	0.018	12.283	0.000
Land size	-0.120	0.012	9.850	0.000
_cons	-3.299	0.816	-4.040	0.000
sigma_v (σ^2)	0.283	0.038		

The amount of manure used was found to have a positive effect on technical efficiency as expected (*P*-value=0.019). This implies that manure was a key input in potato farming. Increase in quantity of manure was attributed to greater potato output. This scenario is consistent with the study expectation that use of manure increases crop yield. The findings of this study agree with Wambua (2021) who studied the factors influencing productivity of green grams and pigeon peas in Machakos County, Kenya and found that farms with no manure application had lower productivity than farms where manure was used by 11.869 kilograms per hectare. Similarly, according to Wambua (2021), adequate quantity and quality of manure explained the difference in output per unit of land area among farmers.

The total costs incurred on agrochemicals such as pesticides (insecticides, nematicides), fungicides and herbicides was found to have a positive effect on technical efficiency as expected (*P*-value =0.000). This implies that agrochemicals were key inputs in potato farming. Increase in quantity of agrochemicals was attributed to greater potato output. Without agrochemicals, farmers suffer from a reduction in quality and quantity of produce due to pests and diseases. Some of the major pests of potato in Kenya include potato tuber moth, aphids, root-knot nematode, spider mites, millipedes, mealy bugs and cutworms. These results agree with SHEP PLUS (2019) who asserted that agrochemicals are part of the main farm inputs required in potato production. These results also agree with many other studies that found that pesticides and herbicides availability and pricing are amid the aspects affecting potato production (Andy *et al.,* 2017; Mutegi *et al.,* 2021; Nyawade *et al.,* 2021).

The coefficients with respect to all input variables used in the analysis were positive, as expected, implying that an increase in capital, seeds, labour, fertilizer, manure and agrochemicals would improve the potato yields per acre. Specifically, a 1% increase in capital, seeds, labour, fertilizer, manure and agrochemicals increased total yields per acre by approximately 0.60%, 0.06%, 0.45%, 0.05%, 0.06% and 0.03%, respectively (see the frontier coefficients in Table II). The estimated gamma parameter (γ) of 0.527 is statistically significant at 5% level, indicating that 53% of the variation in potato yields per acre among the sampled farmers is due to differences in the inputs used in the production. Sigma squared (σ^2) on the other hand is 0.283 and statistically significant at 5% level indicating the suitability of the model as assumed for the composite error term.

The coefficients of all the explanatory variables in the inefficiency model have the expected signs. The coefficients for sex (-0.033), years of education (-0.232), farm income (-0.171), non-farm income (-0.131), group membership (-0.986), access to credit (-0.401), number of extension contacts (-.179), receipt of technical training (-0.843), years of farming experience (-0.220) and land size (-0.120) are statistically significant and positively related to technical efficiency among the sampled farmers (because a negative coefficient implies decrease in technical inefficiency and vice-versa).

The sex of the household head was found to have a negative effect on technical inefficiency (P-vakue =0.008). Negative sign in the coefficient of sex means that being a male reduces the technical inefficiency. This implies that male farmers are more technically efficient in potato farming than their female counterparts. These results contrast with Mukasa and Salami (2015) whom in their study on three African countries (Nigeria, Tanzania and Uganda), found that female farmers had an advantage in terms of productivity over male farmers because they cultivated smaller farms, on average. Rodgers and Akram-Lodhi (2019) investigated the gender gap in agricultural productivity in sub-Saharan Africa (causes, costs and solutions). Rodgers and Akram-Lodhi (2019) whose results agree with this study found that female farmers had lower rates of agricultural productivity than male farmers. Basing the findings in five countries (Ethiopia, Malawi, Rwanda, Uganda, and United Republic of Tanzania), the research revealed that gender gaps in agricultural productivity did not arise because women are less efficient farmers but because they experience inequitable access to agricultural inputs, including family labour, high quality seeds, pesticides, and fertilizer. Equalizing women's access to agricultural inputs, including time-saving equipment, and increasing the return to these inputs is therefore critical to close gender gaps in agricultural productivity. The findings of this study also agree with Yana (2018) who found that women's limited use of agricultural implements and machinery explains 18 per cent of the technical efficiency gender gap in Malawi, 9 per cent in Uganda and 8 per cent in Tanzania. This gender imbalance in access to equipment costed as much as $17.7 million in lost GDP in Malawi (Yana, 2018). One of the main reasons for this gender imbalance in access to equipment is women's lack of cash income given their responsibility for meeting household maintenance needs. According to Yana (2018), female-controlled plots have relatively lower yields because important inputs such as inorganic fertilizer and pesticides are used mostly on male-controlled plots. Since organic fertilizers are usually produced by livestock owned by a household, while inorganic fertilizers are purchased in the marketplace, in most countries, women tend to have less access to both types of fertilizer.

The low number of years of education was found to have a negative effect on technical inefficiency (*P*-value =0.012). This implies that farmers with more years of education are less technically inefficient in potato farming than their counterparts with less years of education. One of the main productive value of education in agriculture is to instill technical efficiency (being able to use the same input to achieve a greater level output - better use of current resources). Education can raise agricultural productivity through improvement in farmer's skills, enhancement of farmer's ability to obtain, understand and utilize, new input, and improvement in overall managerial ability. Attaining a minimum threshold level of education helps farmers in ways of enhancing their skills and capabilities to collect and analyze the information and execute that on the field. It creates a conducive environment to go for modern technology adoption and thereby augments the productivity. The results in this study agree with Linn and Maenhout (2019) who found that education was an important factor, indicating the ability of farmers to receive and understand information on modern technologies and thereby enhancing their technical efficiency. More educated farmers perform better in technical efficiency as a result of their access to information and good farm planning. In support of the findings in this study, Oduro-Ofori *et al.* (2014) found that schooling has positive effects on agriculture due to literacy and numeracy skills that give the farmers better understanding of agricultural issues. Education also influences agricultural productivity indirectly. Likewise, Verter and Bečvářová (2015) found that yam production in Nigeria was positively influenced by educational level of the farmers. The results support Schultz's argument that formal education has a significant marginal contribution to farm production under modern technology. These results are also consistent with other studies like Asfaw *et al.* (2012), Manyong and Alene (2007).

Low farm income was found to have a negative effect on technical inefficiency (*P*-value=0.000) This implies that farmers with more farm income are, understandably, more technically efficient in potato farming than their counterparts with less farm income. Farm income counteracts the vulnerability of smallholder livelihoods. Verter and Bečvářová (2015) found that yam production in Nigeria was positively influenced by income level of the farmers.

Low non-farm income was found to have a negative effect on technical inefficiency (*P*-value =0.000). This implies that farmers with more non-farm income are less technically inefficient than their counterparts with less non-farm income. Off-farm income opportunities have been widely documented as an important strategy for overcoming capital shortages faced by rural households in many developing countries. Many smallholders are unable to invest in agricultural best management practices and technologies due to lack of income. However, securing off-farm income may represent a more attractive and less complicated opportunity, particularly for younger generations leading to a drop in agricultural productivity and an eventual labor crisis in the agricultural sector.

None group membership was found to have a negative effect on technical inefficiency (*P*-value=0.032). This implies that farmers who are members of groups are less technically inefficient in potato farming than their counterparts who are not members of groups. The findings of this study are not consistent with results of Mwaura (2014) who found that there existed some situations where membership to farmer groups does not necessarily lead to adoption of high yielding technologies (e.g. use of inorganic fertilizer) and increased productivity; sometime there can be detrimental effects. According to Mwaura (2014), membership to groups has no advantages in some crop management technologies and, in fact their practices may lead to some enterprises' inefficiency. Similarly, Davis *et al.* (2012) proved that group membership did not result to significant higher crop yields per acre than nonmembers in Uganda.

Lack of access to credit was found to have a negative effect on technical inefficiency (*P*-value=0.000). This implies that farmers who had access to credit were less technically inefficient (more technically efficient) in potato farming than their counterparts who did not have access to credit. The results of this study are similar to Yana (2018) who found that farmers (especially women) who face difficulties in accessing formal credit through commercial banks due to their lack of collateral and exacerbated by weak or non-existent property rights had low levels of productivity. Credit market imperfections in turn can have greater adverse effects on farmers' ability to engage in income-generating activities and purchase farm inputs that could support higher productivity (Palacios-Palacios -López and López, 2015).

Low number of extension contacts was found to have a negative effect on technical inefficiency (*P*-value=0.000). This implies that farmers who had more contacts with agricultural extensionists were less technically inefficient in potato farming than their counterparts who had less extension contacts. Extension provides a source of information on new technologies for farming communities which when adopted can improve their productivity (Bonye *et al.*, 2012). Access to extension and advisory service is an important ingredient for diffusion of new and modern agricultural innovations. These results are consistent with Oduro-Ofori *et al.* (2014) who found that extension service had a significant positive impact on agricultural productivity in Offinso municipality even though coverage is low. This study is consistent with Danso-Abbeam *et al.* (2018) who in their study on agricultural extension and its effects on farm productivity found positive economic gains from participating in the ACDEP agricultural extension programmes in Northern Ghana. The results are also in line with other previous studies (Davis *et al.*, 2012; McGarry, 2008; Meti, 2007; Geer *et al.*, 2006) that reported positive effects of extension programmes on crop productivity. Likewise, the coefficient for receipt of technical training was estimated to be negative (-0.843) and statistically significant at 5% level. This implies that farmers who had received technical training on potato farming were more technically efficient in potato farming than their counterparts who did not receive technical training.

The low number years in farming experience was found to have a negative effect on technical inefficiency (*P*-value =0.000). This implies that farmers who had more years of farming experience were less technically inefficient in potato farming than their counterparts who had less years of experience. According to Sindi (2008), more experienced farmers have more access to required resource as compared to less experienced farmers. While studying output performance of food-crop farmers under the Nigerian agricultural insurance scheme in Imo State, South East, Nigeria, farming experience was found to positively impact farm productivity (Nwosu, *et al.*, 2010). Similarly, Toluwase and Apata (2012) found that more experience in farming led to improved agricultural productivity and enhanced entrepreneurial ability.

Small land size was found to have a negative effect on technical inefficiency (*P*-value =0.000). This implies that farmers who had more land were less technically inefficient in potato farming than their counterparts who had less land. These results agree with Gebre *et al.* (2021) who reported that farmland size had a positive and significant effect on the gross value of maize output per hectare. Similarly, these results are in line with Collier and Dercon (2014), Savastano and Scandizzo (2017), Gollin (2018) and Nwosu *et al.* (2010) who found that land size positively impacted on farm productivity. The results of this study contrast with the findings of Njuki *et al.* (2006) and Mukasa and Salami (2015). According to Njuki *et al.* (2006), the inverse relationship between farm size and productivity in Kenya is related to producers' limited access to and relatively high cost of agricultural inputs. As farmers work on a larger area of land, they are increasingly less capable of using a sufficient amount of input to maintain productivity. In their study on three African countries (Nigeria, Tanzania, and Uganda), Mukasa and Salami (2015) suggest that farmers with smaller land size would have an advantage in terms of productivity over their counterparts with large farm size. Collier and Dercon (2014) and Gollin (2018) argue that small scale farmers are usually not technologically productive (are technically inefficient) due to their proneness to the imperfection in factor (e.g. labour) markets. In their study in Ethiopia, Savastano and Scandizzo (2017) identified a nonlinear significant U-shape relationship between farm size and productivity.

Description of technical efficiency scores assuming variable returns to scale (VRS)

The distribution of farmers' technical efficiency indices derived from the analysis of the stochastic frontier model is presented in Table III.

TABLE III- TECHNICAL EFFICIENCY SCORES

Efficiency index	Frequency	Percentage
0 – 0.1	-	-
0.1 – 0.2	-	-
0.2 - 0.3	8	2.6%
0.3 - 0.4	7	2.3%
0.4 - 0.5	3	1.0%
0.5 - 0.6	13	4.3%
0.6 - 0.7	36	11.8%
0.7 - 0.8	38	12.5%
0.8 - 0.9	135	44.3%
0.9 - 1.0	65	21.3%
Total	305	100.0%

Note: Technical efficiency (VRS): Mean = 0.787; Std. Dev. = 0.157; Min. = 0.248; Max. = 1

The technical efficiency of the sampled farmers ranged from 0.248 to 1.00. The mean technical efficiency is estimated to be 0.787, meaning that an average farmer in the study area has the scope for increasing technical efficiency by 21.3% in the short-run under the existing technology. Majority of the respondents (about 44.3%) had technical efficiency of 80 - 90%.

CONCLUSION AND RECOMMENDATIONS

Sex, years of education, farm income, non-farm income, group membership, access to credit, number of extension contacts, receipt of technical training, years of farming experience and land size are important factors that influence the level of technical efficiency among smallholder potato farmers in Kenya. Thus, all policy measures that are geared towards enhancement of smallholder farmers productivity in potato farming (through technical efficiency approach) should endeavor to address unique challenges that face female farmers in input acquisition, information access, level of farming skills and land access. Farmers with inadequate skills and experience in potato farming should be supported in benefiting from technical trainings and regular extension services. Farmers organizations should also be strengthened in order to serve as an important vehicle for credit and trainings/extension services which are key ingredients of increased productivity.

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