ASSESSMENT OF TECHNICAL EFFICIENCY OF OPEN FIELD PRODUCTION IN KIAMBU COUNTY, KENYA (STOCHASTIC FRONTIER APPROACH)

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Abstract

The study conducted an estimate of the mean technical efficiency and the determinants of technical efficiency for the open field tomato farmers in Kiambu, Kenya. A multistage sampling technique was used to draw a sample of 75 respondents who participated in the study. The method of analysis used was a two stage approach; a Cobb Douglas stochastic frontier analysis and a Tobit regression to compute the mean technical efficiency and determine factors influencing technical efficiency respectively. All the analyses were computed using Stata versions 13. Results indicated a mean technical efficiency of 65 percent ranging from 26.7 percent to 96.3 percent implying that there is room to increase efficiency by 35 percent. Education, family size and experience positively influenced technical efficiency while gender and farm size had a negative significant influence. The study demonstrated that farmers had a lower level of experience (5 years) and education (9 years) as compared to the national and other local areas within the country despite their positive significant influence on technical efficiency. The implication from the study findings is that greater attention should be paid towards farmer training to enhance their knowledge and farming experience with regard to tomatoes. A few farmers had received credit (16%), extension (14%) and agriculture support facilities (8%). Extension is very important as it bridges the gap between researchers and farmers whereas credit access enables farmers to buy farming inputs like fertilizers. Investments in farmer education without appropriate dissemination techniques may not cause any impacts. The study therefore recommends that accessibility to these services be enhanced.

Key words: technical efficiency, Cobb – Douglas production function, open tomato production

1.0 Introduction

Vegetable production among the small holder farmers has been key in income provision and poverty alleviation within Kenya (Mithöfer et al., 2008) . Among the horticultural produce exported, vegetables had the largest share with a volume of 77,200 tones by the year 2013 (Kenya Economic Survey, 2014). Tomatoes account for 6.72 percent and 14 percent of the total production of horticulture and vegetables respectively. In 2011 , tomato production yielded a value of Kshs. 12,354 million under a production area of 18,178 ha (Njoroge, 2014).

The role of tomato farming in the Kenyan economy cannot be overemphasized. It is a source of livelihood to people along the value chain including farmers, traders, processors and transporters (Mueke, 2015). It contributes in food security, employment, foreign exchange and it has been key in alleviation of poverty especially in rural areas where production is intensive (Sigei *et al*., 2014). Despite this significant contribution of tomato production in the country's economy, productivity is still very low. In fact the actual yield for all agriculture products has been low compared to maximum predicted yields (Calzadilla *et al*., 2009). In 2013, it was estimated that the average agricultural yield in Sub Saharan Africa was 2-3 times lower compared to the global average (Ndungu *et al*., 2013). For example average tomato yield in Kenya is estimated at 12t/ ha which is lower than an average of 35t/ha and 120t/ha estimated for Egypt and France respectively (Mueke, 2015).

The low productivity within the agriculture sector has been also attributed to farmers' inability to fully exploit available technologies hence resulting into inefficiencies in the production system (Murthy *et al*., 2009). The enormous population growth, urbanization and rampant soil degradation due to poor farming practices in Sub-Saharan Africa (SSA) has lessened available land for agricultural activities, lowering productivity and making it hard to alleviate poverty (Calzadilla *et al*., 2009). Furthermore, the massive poverty levels coupled with limited factors of production has made it extremely hard for farmers to uplift production through the use of more inputs.

In addition, agriculture production including tomato growing has been undermined by the changing climate with adverse effects in Sub-Saharan Africa. It is well documented that the impacts of climate change have been severe in Africa than in any other part of the globe. In Kenya, temperature increments have been already evidenced and the projected median temperature increment is predicted to be greater than the global averages (Bryan *et al*., 2013). The Intergovernmental Panel on Climate Change (IPCC) has projected that if greenhouse gas emissions which is the leading cause of climate change continues to rise, the mean global temperatures will increase by between 1.4 and 5.8°C by the end of the 21st century (IPCC, 2007).

In the course of increasing agriculture productivity and adaptation to climate change, modern technologies have been developed. These include biological and biotechnology technologies which involve development of superior varieties like drought resistant varieties, pest resistant varieties and high yielding varieties. Chemical technologies which involve innovations like development of new and superior pesticides (fungicides, nematicides), herbicides, growth stimulants, fertilizers and mechanical technologies aimed at reducing production costs for example green houses and tractors (Nzomoi et al., 2007) .

Despite the various agriculture technological innovations, moderate food increments have been observed in the recent past. The increase in food production has been attributed to an increase in the area under production and not technology and efficiency advancements (Dethier and Effenberger; 2012, Toenniessen *et al*., 2008). It is believed that efficient use of technologies to improve agriculture productivity would be more cost effective than inventing new agriculture innovations (Adeleke *et al*., 2008).

Efficiency in production refers to the farms' ability to produce maximum output from the least input combination during the production process (Musaba, 2014). Economic efficiency has been broken down into technical and allocative efficiency. Allocative Efficiency refers to a situation where a firm uses the least combination of inputs to produce a given quantity of outputs in the light of prevailing prices (Porcelli, 2009) whereas technical efficiency refers to the farms' ability to produce along the production frontier. Frontier approaches have been extensively used in measuring efficiency. Farrell (1957) categorized these approaches into parametric and non- parametric measures. The non-parametric approach also known as a deterministic technique uses a linear programming technique to construct a piece wise production frontier which is used to evaluate relative efficiency and Decision Making Units (DMU) in a firm. The deterministic frontier production function was first estimated by Aigner and Chu (1968) using a Cobb-Douglas production function. However, the approach cannot estimate model parameters and therefore cannot allow for hypothesis testing of the fitness of the model. In addition , it does not provide a direct relationship between the inputs and outputs used and it also interprets all unknown variations (noise) as inefficiencies which results into estimation errors (Kiprono, 2013). Due to the fact that random shocks like measurement errors can also affect the output, the deterministic model was later extended by Aigner et al. (1977) and Meeusen and Van den Broeck (1977) to the stochastic production frontier to account for measurement errors and statistical noise as well as technical inefficiency. In order to use SFA, the distribution function of the error term must be specified. These distributions include the Cobb- Douglas (CD) which is a restrictive and the simplest form of the production function , the transcendental, translog, the normalized quadratic and Leontief production functions (Abdulai and Huffman, 2000).

Assessment of technical efficiency levels provides an understanding of what makes an efficient system and how to improve efficiency and hence productivity. In addition, efficient resource utilization has a potential to increase food production without necessarily increasing resource use like production area. This therefore drives the need to augment agricultural productivity through increasing efficiency of available technologies and resources. This in effect provides an input to farmer decision making that could improve productivity by ensuring maximum output from resources used without necessarily increasing the cost of production. Hence the main objective of the present study was to assess the technical efficiency for open field tomato farmers in Kiambu County. It determined the mean technical efficiency of open field tomato farmers and also underscored the socio-economic factors influencing technical efficiency.

2.0 Materials and Methods

The study was conducted in Kiambu County, Kenya. Kiambu County contributes 5.2% (approximately 20,644 tons) of the total tomato production in Kenya (Sigei *et al*., 2014). Central counties, together with the Rift valley area and Nyanza counties contribute 80% of the total tomato production in Kenya (Odame *et al*., 2009). A multistage sampling technique was used. The First stage of sampling was purposive selection of Kiambu County and five sub counties namely Thika, Juja, Ruiru, Gatundu South and Gatundu North. The county and sub counties were purposively selected because they are the main tomato producing areas within the country and county respectively. In 2013, a total production value of Ksh 884 million was registered in Kiambu County under a production area of 930 hectares (Horticulture Crops Directorate, 2013). The area is also easy to access and tomato farmers can be easily identified through the aid of agriculture extension workers. A list of tomato farmers using open field tomato production system was generated through an exploratory survey for each of the sampled sub counties. A total of 240 open field tomato producing farmers were listed across the sub-counties with the help of agricultural extension officers. From this list, simple random sampling technique was used to sample farmers from each sub county. Proportional sampling technique was then used to determine the number of farmers sampled from each sub county. A total of 120 respondents was computed using a formula as provided by Naing *et al*. (2006). The data for all the 120 study cases was entered into the STATA (version 13) computer software. However, 47 of them were automatically excluded from the stochastic frontier model estimation procedure due to missing responses. Hence, only 73 respondents were involved in the analysis. This sample size was statistically satisfactory and sufficient (i.e. greater than 30 observations) to draw scientific conclusions.

The target population of the study was of small scale tomato farmers using open field production system in Kiambu County. Small scale farmers were defined as those cultivating two acres of tomatoes and below. A pre tested questionnaire was administered through a face to face interview and the resulting data analyzed using STATA (version 13) for statistical analysis. A stochastic Frontier Analysis using Cobb Douglas, Quadratic and Translog models were performed to determine the mean technical efficiency while factors influencing technical efficiency were determined using a normal Tobit regression model. The model variables measured were: quantity of labor used, tomato planting seeds, quantity of fertilizer used, pesticides and area of farm under tomatoes.

3.0 Theoretical Framework

A stochastic Frontier Analysis (SFA) using a Cobb Douglas production function was used in the present study. This is because unlike the non-parametric approaches, the parametric approaches (stochastic) provide room for differentiating between random error and inefficiency (Malinga *et al*., 2015) and the approach is also less sensitive to outliers. The Cobb Douglas was used because it allows for hypothesis testing and is efficient for multiple inputs modeling. It is the simplest model and provides an efficient way of handling multi collinearity, heteroscedasticity and correlations. Nevertheless other functional forms were also tested.

4.0 Empirical Model Specification

The Stochastic Frontier Analysis (SFA) equation can be expressed as:

$$Yi = f(Xi\beta)e^{v-u} \quad \ldots\ldots(1)$$

The SFA function can also be expressed in a logarithm form as:

$$lnYi = Inf(Xi\beta) + Vi - Ui \quad \ldots\ldots(2)$$

Where

Yi = output level of i[th] farm, *X* = vector of inputs of i[th] farm, *β* =vector of unknown parameters, *Vi* = a symmetric error term, representing random variation in output due to random exogenous variables and it is independently and identically distributed (*iid*) and also independently distributed of u_i. *Ui* = a non-negative error term representing the stochastic shortfall in maximum achievable output(Y) from the production frontier due to output-oriented technical inefficiency. The study used a Cobb Douglas production function and the model specification is expressed below:

$$Y_i = \beta_0 X_1^{\beta 1}\, X_2^{\beta 2}\, X_3^{\beta 3} \ldots X_5^{\beta 5}\, e^{(Vi-Ui)} \quad \ldots\ldots (3)$$

To enable the use of least square estimation procedure, the Cobb Douglas function in equation 3 was transformed into a linear regression by expressing it in a logarithm form as shown below:

$$lny_{i=}\beta_0 + \beta_1\, lnX_{1i} + \beta_2\, lnX_{2i} + \cdots + \beta_5\, lnX_{5i} + V_i + U_i \quad \ldots\ldots (4)$$

Where ln= natural logarithm to base e

Yi= total tomato output (number of crates)

β_0 = Intercept

$\beta_1 - \beta_6$ = unknown parameters to be estimated

X_1= quantity of labor used (man days)

X_2= quantity of tomato seeds (kg)

X_3= quantity of fertilizers (kg)

X_4= quantity of pesticides (litres)

X_5= Area under tomatoes (acres)

V_i= Random error

U_i= random error variables accounting for technical inefficiency. These variables include the social economic characteristics of tomato farmers and were specified in the technical inefficiency model below:

$$U_i = \alpha_0 + \alpha_1 Z_1 + \alpha_2 Z_2 + \cdots + \alpha_5 Z_5 \quad (5)$$

Where α_0=intercept

α_1 -α_{11} = unknown parameters

Z_1=age of farmers (years)

Z_2= educational level (years spent in school)

Z_3= Farmers experience (years)

Z_4= Household size

Z_5**=** gender of the farmer

5.0 Results and Discussion

The various farmer, farm and institutional characteristics of tomato production among sampled tomato farmers in Kiambu were given in Table 1.

Table 1: Descriptive statistics of farmer, farm and institutional characteristics

Variable	**Unit**	**Mean**	**Sd**	**Max**	**Min**
Age	Years	40.0	9.2	67.0	24.0
Education	Years	9.0	4.9	17.0	0.0
Experience	Years	5.0	2.9	12.0	1.0
Family size	Numbers of people	4.2	1.5	8.0	1.0
Gender(Female=1, Males= 0)		0.45	0.50	1	0
Credit(1=yes, 0= no)		0.15	0.36	1	0
Extension(1=yes, 0= n0)		0.14	0.35	1	0
Agriculture support(1=yes, 0=no)		0.04	0.199	1	0
Farm size	Acres	1.46	0.09	4.0	0.25
Tomato farm size	Acres	0.32	0.17	1.0	0.1

Amount of fertilizer used per acre	Kilo grams	211	104	600	0.0
Amount of pesticide used per acre	litres	3.7	2.12	14.4	0.56
Amount of seeds used per acre	Kilo grams	0.15	0.14	0.8	0.04
Number of workers per acre	Man days	416	218	1000	120
Tomato yield per acre	Kilo grams	3879	1645	8000	720

The mean age for respondents was 40 years while the mean years of schooling was 9. Years spent by farmers in school ranged between 0 and 17 also indicating that some farmers have never attained any education. The mean of 9 years of formal education is in contrast with the national mean of 11years as reported in the Republic of Kenya (RoK) Human Development Report 2015 hence an indication of lower education levels among the tomato farmers in Kiambu. In addition, the mean experience in tomato production was 5 years while average family size was 4.2 persons per family. Compared to national and rural Kenyan average family size of 4.4 and 4.7 persons per family (Maithya *et al.*, 2007) respectively, the mean family size observed in Kiambu County was lower. This could be because Kiambu is near Nairobi and the land sizes are too small to accommodate large families. Being close to Nairobi could also mean they have access to population control messages.

The mean farm size used by farmers for tomato production was 1.44 acres which also ranged from 0.25 to 3.95 acres. Of the 1.44 mean acre farm size owned by farmers, a mean of 0.32 acres was under tomato production which is less than a quarter of the total farm size. The use of less than a quarter of land on tomato production could mean that the farmers have other alternative activities practiced including growing of other crops like green pepper and small scale animal rearing. Majority of the respondents did not receive any credit (84%), extension (86%) and agriculture support facilities (96%). Among the minority (14 percent) who had received extension services, most of them claimed having received extension from input dealers who visit the farms to promote and sell their agricultural products like pesticides, seeds and fertilizers. Farmers used an average of 211 kilo grams of fertilizers per acre of a tomato field. This average is an estimate of all fertilizers used including nitrogen, phosphorus and potassium.

In tomato production, the recommended doses for nitrogen, phosphorus and potassium are 100 kilograms per acre for nitrogen and 190 kilograms per acre for each of phosphorus and potassium. This all together gives a total of 480 kilograms per acre for nitrogen, phosphorus and potassium. Compared to the average of 211 kilograms observed in Kiambu, the implication is that farmers used less than the recommended doses of fertilizers.

Results in Table 1 further reveal that an average of 3.7 litres of pesticides was used by farmers per acre. In addition, a mean of 0.15 kilo grams of tomato seeds and 416 workers in man days per acre were used on tomato farms. With all the above inputs, the study revealed a mean yield of only 3879 kilo grams of tomatoes harvested per acre. The observed yield is far low compared to the national average yield of 12280 kilo grams per acre (Mwangi, 2012). The deviance in yield between the national and that observed in Kiambu County may be associated to the presence of inefficiency within tomato production.

6.0 Technical Efficiency Using SFA

To obtain the technical efficiency estimate, a stochastic frontier analysis approach was used with different functional forms. The mean technical efficiency estimated was 68, 65, 66 and 65 percent for a translog, Cobb Douglas, quadratic and transcendental functional forms respectively as shown in Table 2. Similarly, the mean technical efficiency estimate from a translog production function was 3 and 2 percent higher than that for quadratic, Cobb Douglas and transcendental production functions respectively. The determination of technical efficiency makes use of a Cobb Douglas instead of a translog production function form. Table 3 presents the results of the hypothesis testing for the best functional form between the Cobb Douglas and the translog.

Table 2: Technical efficiency from different production functional forms

VARIABLE	PARAMETERS	TRANSLOG	COBB DOUGLAS	QUADRATIC	TRANSCENDENTAL
INTERCEPT	ß0	-8.318437***	4.262312***	-0.6237892	1.679091
LNFERT	ß1	2.360417***	0.2953912 ***	2.202142*	0.439518
LNLABOR	ß2	2.831115***	0.2928647**	.3292465**	0.5895783*
LNPESTICIDE	ß3	-0.1674118***	0.1211908 *	-0.4314952	0.2083839
LNSEED	ß4	0.3833992***	0.0756731	0.8291772*	0.2082407*
LNTOMATOLANDSIZE	ß5	0.1679682***	0.1820911	0.0586254	0.7009491
LNFERTSQ	ß6			-0.1841148	
LNLABORSQ	ß7	-.0315805***			
LNPESTICIDESQ	ß8			0.0362146	
LNSEEDSQ	ß9	-0.0634543***		-0.0779599	
LNTOMATOLANDSIZESQ	ß10			-0.0413594	
LNFERTILIZER-LNPESTICIDE	ß11	0.0478752***			
LNFERTILIZER-LNLABOUR	ß12	-0.421959***			
LNFERTILIZER-INTOMATOLANDSIZE	ß13	0.00326***			
LNSEED-LNLABOUR	ß14	0.0443174***			
TOMATO FARM SIZE	ß14				-0.8698247
FERTILIZERS	ß15				-0.0003739
PESTICIDES	ß16				9.12e-06
SEEDS	ß17				-0.000619
FERTILIZER_SEED	ß18				-1.48e-07
FERTILIZER _LABOUR	ß19				-1.64e-06
PESTICIDE_LABOUR	ß20				-3.46e-07
INEFFICIENCY MODEL					
CONSTANT	δ0	0.5347291***	0.4636424 ***	.4748669***	0.4886364***
EXPERIENCE	δ1	0.0267729***	0.0234811 ***	0.0188855**	0.0199977***
EDUCATION	δ2	0.0140763**	0.0131869 ***	0.0140221***	0.0131257***
FARM SIZE	δ3	-0.0546*	-0.0474034 **	-0.044579*	-0.0438545*
FAMILY_SIZE	δ4	0.0214354	0.0245813 *	0.0287252*	0.0235866
GENDER	δ5	-0.1675167***	-0.0785755 *	-.0882608**	-0.0893508**
AGE	δ6	-0.0003649	-0.0010691	-0.0010884	-0.0009409
VARIANCE PARAMETERS					
SIGMA V	σ_u^2	4.58e-09	0.086022	0.5980646	0.076487
SIGMA U	σ_v^2	0.580102	0.610748	0.0782611	0.6042516
SIGMA SQUARED		0.580102004	0.69677	0.6763257	0.680742
GAMMA	Γ	0.99	0.88	0.12	0.89
LAMBDA	Λ	1.27e+08	7.18229	7.641913	7.900053

LOGLIKELYHOOD	-12.868039	-25.10	-22.293475	-22.783817
TECHNICAL EFFICIENCY	68.62	65.5	66.24	65.6

***, **,* significance level at 1%, 5% and 10% respectively.

Table 3: Hypothesis testing for the best functional form between cob Douglas and Translog

Hypothesis	L(H0)	L(H1)	Df	χ2 calculated	χ2 critical	Decision
H0=B6=B7...B14 =0	-25.10	-12.86	4	-3.90	9.49	Fail to reject H_0

From Table 3 above, $H_0 = \beta_6 = \beta_7 = \ldots \beta_{14} = 0$ is a null hypothesis stating that all additional variables in the translog production function equal to zero. The test statistics was calculated as:

$\chi^2 = LR = -2\{[\ln H_0]/ [\ln H_1]\}$.

The computed chi square (-3.90) is smaller than the tabulated (9.49) chi square and hence falls in the no rejection area. This implies that there is no enough evidence to reject the null hypothesis and hence a conclusion is made that the additional variables in a translog production function equal to zero. The implication is that the Cobb Douglas function is a good presentation of the data since additional variables in translog do not carry any meaning. In addition, the translog production function faces serious challenges in terms of result feasibility due to variable multicollinearity (Pavelescu, 2011). The number of model variables increases with the number of production factors taken into account. This at times result into a failure to converge and where ridge regressions are used to solve the problem, the end results are distorted. Like in the translog model in Table 2, some variables were not included in the model because of failure to converge when they are included and hence making the model incomplete. Results for Cobb Douglas production are presented in Table 4.

The mean technical efficiency estimate was 65 percent. The minimum technical efficiency computed was 26.7 percent while the maximum was 96.3 percent. This means that there is room to improve the technical efficiency among tomato growers in Kiambu by 35 percent if constraints which make them inefficient are worked upon. The mean technical efficiency score estimated in the present study is comparable with the results attained by previous similar studies. For example, Donkoh *et al*. (2013), estimated a mean technical efficiency of 71 percent for tomato farmers in Northern Ghana whereas Ajibefun and Daramola (2003) estimated a mean technical efficiency of

Table 4: Technical efficiency using Cobb Douglas production model

Variable name	Parameter	coefficients	Std. Error	Z vale	P value	95% Conf interval
INTERCEPT	ß0	4.262312	0.8991247	4.74	0.000	2.50006- 6.024564
LNFERTILIZER	ß1	0.2953912	0.0859991	3.43	0.001	0.126836-0.463946
LNPESTICIDE	ß2	0.1211908	0.0677126	1.79	0.073	-0.01152- 0.253905
LNSEED	ß3	0.0756731	0.0612959	1.23	0.217	-0.04446- 0.195811
LNLABOUR	ß4	0.2928647	0.1460345	2.01	0.045	0.006642-0.579087
LNTOMATOLANDSIZE	ß5	0.1820911	0.1176262	1.55	0.122	-0 .04845-0.412634
VARIANCE PARAMETERS						
SIGMA V	δ_V	0.086022				
SIGMA U	δ_U	0.617835				
GAMMA, $\Sigma_U^2/(\Sigma_U^2+\Sigma_V^2)$	Γ	0.88				
LN (LIKELIHOOD)		-25.10				
MEAN TECHNICAL EFFICIENCY (%)		65%				

***, **,* significance level at 1%, 5% and 10% respectively.

66 and 57 percent for rural and urban small scale farmers in Nigeria respectively. The majority (frequency =17) of the farmers had technical efficiency ranging from 70 to 84 percent. A few farmers (frequency =12) had technical efficiency ranging between 25 to 39 percent which was also the lowest efficiency estimate. 16 farmers had technical efficiency greater than 85 percent. Figure 1 presents the distribution of technical efficiency which was skewed to the right.

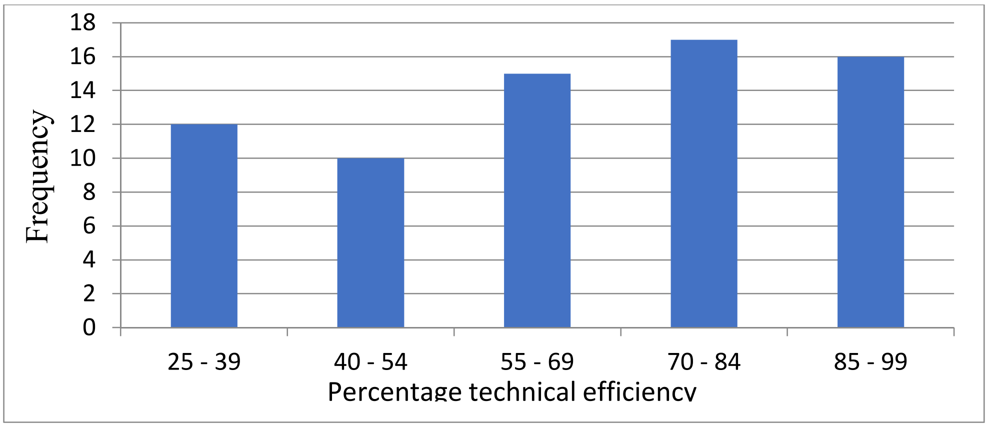

Figure 4: Frequency distribution of predicted technical efficiency

7.0 Technical efficiency and Social Economic Characteristics

The study also investigated factors which bring about technical inefficiency within the study area among tomato farmers which included; age, education level, experience, family size, farm size and gender. Results for technical efficiency and social economic characteristics are presented in Table 5.

Table 5: Technical efficiency and social economic characteristics

Variable name	parameter	coefficients	Std.Error	Zvale	Pvalue	95% Conf interval
Constant	δ_0	0.4637534	0.116113	3.99	0.000	.2318598-0.6956471
Experience	δ_1	0.023475	0.0073535	3.19	0.002	.0087892-0.0381609
Age	δ_2	-0.00107	0.0024599	0.43	0.665	-.0059827-0.0038427
Education	δ_3	0.013185	0.0045896	2.87	0.005	.004019-0.022351
Family_Size	δ_4	0.0245792	0.0148625	1.65	0.100	-.0051033-0.0542618
Gender	δ_5	-0.0785805	0.0413712	-1.9	0.062	-.1612044-0.0040435
Farmsizeacres	δ_6	-0.0474003	0.0237703	1.99	0.05	-.0948729-0.0000723

***, **,* significance level at 1%, 5% and 10% respectively.

Experience (p-value =0.002) was found to have a positive and significant influence on technical efficiency. A positive coefficient implies that the variable increases efficiency and therefore reduces inefficiency. In Kiambu, mean years of tomato production was only 5 which is low compared to a mean of 11.5 years observed among tomato farmers in Nakuru District by (Mwangi, 2012)**.** A graphical representation of technical efficiency and experience is presented in Figure 2. These results imply that farmers with more experience have higher efficiency and hence greater productivity than those with less experience.

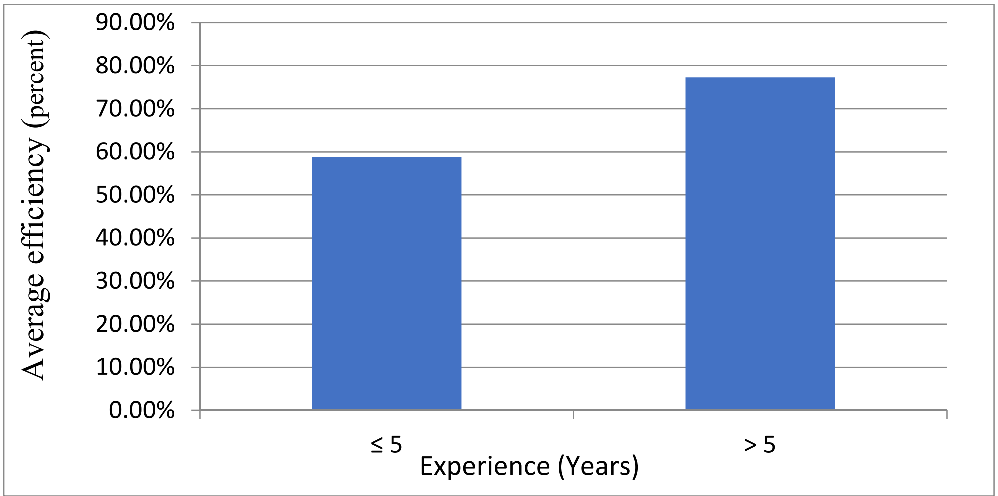

Figure 2: Experience and average technical efficiency

It was observed that farmers with an experience of more than 5 years of tomato production had an average of 72 percent technical efficiency whereas those with less than 5 years of experience had a lower technical efficiency of about 58 percent. In addition, education (p-value= 0.005) was found to significantly affect technical efficiency positively. This also means that education increases efficiency and therefore reduces technical inefficiency. In Kiambu, it was observed that farmers who had more years of formal education and experience in tomato production could easily identify the fertilizers, pesticides and varieties of tomatoes used and grown respectively and they were also informed about the when, how and how much of these chemicals should be used. This therefore implies that educated and experienced farmers are more knowledgeable about modern farming practices and can make maximum use of inputs. Education and experience also put farmers in a better place to manage their social and economic farm characteristics in a way that increases efficiency (Al-Hassan, 2008) . This finding of the study is in line with the findings of Tefaye (2014) and Donkoh *et al*. (2013) which also showed that education negatively relates to technical inefficiency. The relationship between education and technical efficiency is presented in Figure 3.

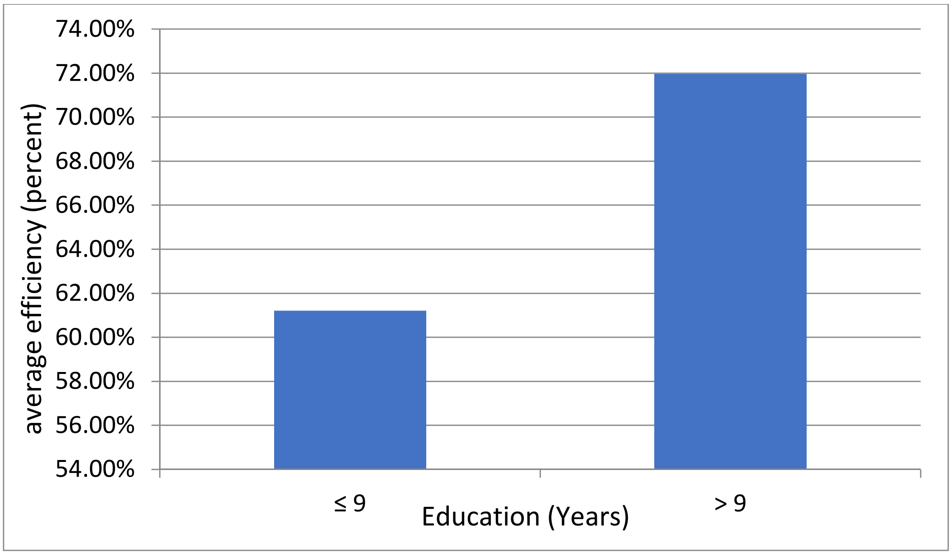

Figure 3: Education and average technical efficiency

Farmers with an education level of more than 9 years had a higher (72 percent) technical efficiency than those farmers who had less than 9 years of formal education.

Results further revealed that family size (p-value = 0.1) also influenced technical efficiency positively. This means that family size increases efficiency and hence reduces technical inefficiency. The average family size was observed to be 4.2 persons per family which is lower than the national and rural Kenya average family size of 4.4 and 4.7 persons per family respectively. Large family sizes have got greater access to labor and information concerning markets, input availability and credit facilities and thus increasing efficiency.

Regarding socio economic factors influencing technical efficiency, farm size and gender were found to have a negative significant influence on technical efficiency with p-values 0.05 and 0.06 respectively. This implies that these factors reduce efficiency and hence increase technical inefficiency. It was observed that farmers with large farm sizes participated in a diversity of farm activities for example poultry production and growing of other crops like green pepper, cabbage and maize. This reduces resources allocated to tomato production hence the low efficiency observed may be attributed to inadequate resource allocation due to existence of competing enterprises. Figure 4 demonstrates the relationship between farm size and technical efficiency.

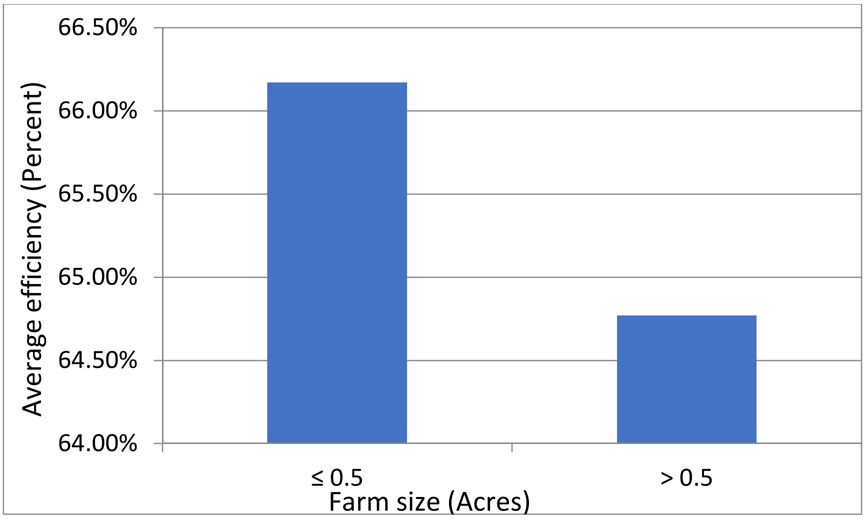

Figure 4: Farm size and average technical efficiency

It was observed that farmers with small pieces of land (less than 0.5 acres) had a higher technical efficiency (greater than 65 percent) compared to those farmers who owned greater than 0. 5 acres of land. The latter category of farmers with more 0.5 acres of land had an average of less than 65 percent technical efficiency.

Gender was coded 0 and 1 for male and female respondents respectively. A negative coefficient for gender therefore implies that female farmers are reducing technical efficiency and hence increasing inefficiency. This may be attributed to the fact that female farmers have got less accessibility to facilities like credit, land and markets hence unable to produce efficiently. From the descriptive results above (see Table 1), only 16, 14 and 4 percent of the farmers had received credit, extension and agriculture support facilities respectively. This therefore implies that the observed low technical efficiency may be due to inadequate credit, extension and agriculture support facilities. Also compared to the male farmers, Figure 5 shows that female farmers were less efficient.

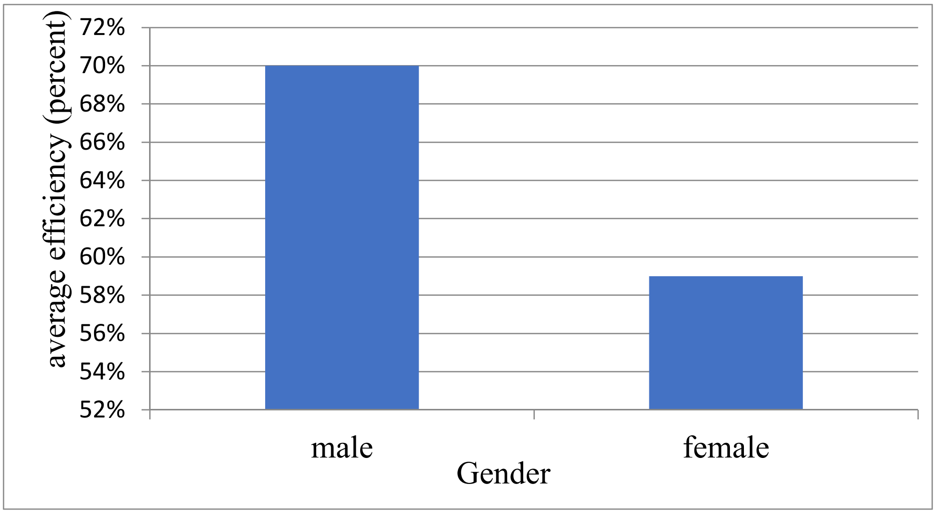

Figure 5: Gender and average technical efficiency

The male farmers had an average of 70 percent technical efficiency whereas the female farmers had a mean technical efficiency of only 61 percent.

8.0 Conclusion and Recommendations

The study determined and assessed the mean technical efficiency and factors influencing efficiency among open field tomato farmers in Kiambu County. A two stage analysis was used which included estimation of technical efficiency using a Cobb Douglas stochastic frontier approach and determination of the factors influencing technical efficiency using a Tobit regression model. The data used was collected through personal interviews using pretested questionnaires from 75 households in Kiambu County. Results from the analysis indicated a mean technical efficiency of 65 percent which ranged from 27 percent to 96 percent. A mean technical efficiency of 65 percent implies that there is room to improve efficiency by 35 percent if such factors undermining it are worked upon. As regards the determinants of technical efficiency, fertilizer use, labour and pesticide influenced technical efficiency both positively and significantly. In addition, among the social economic factors assessed, education, experience and family size were found to influence technical efficiency positively. This implies that these factors are key to reducing technical inefficiency. The study recommends that the government and other responsible bodies should put in place policies to enhance farmers' education and experience. This may be achieved by investing in farmer training through organizing agricultural seminars, workshops and farmer field schools. On the other hand, farm size and gender were found to influence technical efficiency negatively and hence drawing an implication that they increase inefficiency. The negative influence of farm size and gender on efficiency may be attributed to the fact that large farm sizes participated in a diversity of farm activities and hence reducing resources allocated to tomato production. Also the finding that female farmers were found to reduce efficiency may be attributed to the fact that females have got less access to facilities like credit, land and markets hence unable to produce efficiently. A few farmers had received credit (16%), extension (14%) and agriculture support facilities (8%). Extension is very important as it bridges the gap between researchers and farmers whereas credit access enables farmers to buy farming inputs like fertilizers. Investments in farmer education without appropriate dissemination techniques may not cause any impacts. The study therefore recommends that accessibility to these services be enhanced. The government has hired extension workers but the problem is they don't reach to the farmers. Facilities like transport should be availed to ensure that extension workers reach out to farmers. In addition, strict laws should be put in place to monitor and follow up these extension workers.

References

Abdulai, A. and Huffman, W. 2000. Structural Adjustment and Economic Efficiency of Rice Farmers in Northern Ghana. *Economic Development and Cultural Change,* 48**,** 503-520.

Adeleke, O., Matanmi, H. and Ogunniyi, L. 2008. Application of the Normalized Profit Function In The Estimation of the Profit Efficiency Among Smallholder Farmers In Atiba Local Government of Oyo State. *Journal of Economic Theory,* 2**,** 71-76.

Aigner, D., Lovell, C. K. and Schmidt, P. 1977. Formulation And Estimation of Stochastic Frontier Production Function Models. *Journal of Econometrics,* 6**,** 21-37.

Aigner, D. J. and Chu, S.-F. 1968. On Estimating the Industry Production Function. *The American Economic Review***,** 826-839.

Ajibefun, I. A. and Daramola, A. G. 2003. Determinants of Technical and Allocative Efficiency of Micro-Enterprises: Firm-Level Evidence from Nigeria. *African Development Review,* 15**,** 353-395.

Al-Hassan, S. 2008. Technical Efficiency of Rice Farmers in Northern Ghana. African Economic Research Consortium.

Bryan, E., Ringler, C., Okoba, B., Koo, J., Herrero, M. and Silvestri, S. 2013. Can Agriculture Support Climate Change Adaptation, Greenhouse Gas Mitigation And Rural Livelihoods? Insights From Kenya. *Climatic Change,* 118**,** 151-165.

Calzadilla, A., Zhu, T., Rehdanz, K., Tol, R. S. and Ringler, C. 2009. Economywide Impacts Of Climate Change On Agriculture In Sub-Saharan Africa. International Food Policy Research Institute (Ifpri) And University of Hamburg.

Dethier, J.-J. and Effenberger, A. 2012. Agriculture And Development: A Brief Review of the Literature. *Economic Systems,* 36**,** 175-205.

Donkoh, S., Tachega, M. and Amowine, N. 2013. Estimating Technical Efficiency Of Tomato Production in Northern Ghana. *American Journal Of Experimental Agriculture,* 3**,** 56-75.

Farrell, M. J. 1957. The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society. Series A (General)***,** 253-290.

Horticutlure Crops Directorate, 2013. Retrieved on 12th November 2015 From *Www.Jica.Go.Jp/Kenya/English/Office/Others/C8h0vm000001pzr0-Att/Report**2013**.Pdf.*

Intergovernmental Pannel on Climate Change (Ipcc), 2007. Ipcc Fourth Assessment Report: Climate Change, 2007. https://www.ipcc.ch/publications_and_data/ar4/wg1/en/spmsspm-projections-of.html.

Kenya Economic Survey, 2014. Retrieved 15th December 2015 From *Www.Knbs.Or.Ke/Index.Php?...**Econo**...*

Kiprono, P. K. 2013. Economic Efficiency of Resource Use Among Smallholder Tea Producers In Selected Counties of Kenya. Department of Agricultural Economics and Resource Management, Moi University.

Maithya, H. M., Taylor, W., Kilungo, J. K., Mghenyi, E., Agaya, B. M., Asunza, M., Mburu, M. W., Alufa, J., Chemining'wa, G. and Kimani, P. 2007. *Urban Families Under Pressure In Kenya And The Impact Of Hiv/Aids*. University of Birmingham. International Development Department. Working Paper 2. Published In December, 2007.

Malinga, N., Masuku, M. and Raufu, M. 2015. Comparative Analysis of Technical Efficiencies of Smallholder Vegetable Farmers With And Without Credit Access In Swazil And the Case of the Hhohho Region.

Meeusen, W. and Van Den Broeck, J. 1977. Efficiency Estimation From Cobb-Douglas Production Functions With Composed Error. *International Economic Review***,** 435-444.

Mithöfer, D., Nang'ole, E. and Asfaw, S. 2008. Smallholder Access To the Export Market: the Case of Vegetables In Kenya. *Outlook On Agriculture,* 37**,** 203-211.

Mueke, P. M. 2015. *Insect Pest Incidences And Yields of Tomatoes Grown In High Tunnel And In Open Field In Mwea Division, Kirinyaga County, Kenya.* Kenyatta University.

Musaba, E., and Bwacha, I. (2014). Technical Efficiency of Small Scale Maize Production In Masaiti District, Zambia: A Stochastic Frontier Approach. *Journal of Economics And Sustainable Development*, *5*(4), 104-111.

Murthy, D. S., Sudha, M., Hegde, M. and Dakshinamoorthy, V. 2009. Technical Efficiency And Its Determinants In Tomato Production In Karnataka, India: Data Envelopment Analysis (Dea) Approach. *Agricultural Economics Research Review,* 22**,** 215-224.

Mwangi, W. J. 2012. Comparative Analysis of Greenhouse Versus Open-Field Small-Scale Tomato Production In Nakuru-North District, Kenya. Unpublished Msc. Thesis, Egerton University.

Naing, L., Than, W. and Rusli, B. 2006. Practical Issues In Calculating the Sample Size For Prevalence Studies. Archives of Orofacial Sciences 2006; 1: 9-14.

Ndungu, S. K., Macharia, I., Kahuthia-Gathu, R. and Wahome, R. G. 2013. Impact of Organic Vegetable Production System In Kiambu And Kajiado Counties of Kenya. *Journal of Environmental Science And Engineering. A,* 2**,** 256.

Njoroge, H. W. 2014. *Management of Root-Knot Nematodes And Fusarium Wilt of Tomato By Pre-Treatment of Seedlings With Chemical And Biological Agents.* University of Nairobi.

Nzomoi, J., Byaruhanga, J., Maritim, H. and Omboto, P. 2007. Determinants of Technology Adoption In the Production of Horticultural Export Produce In Kenya. *African Journal of Business Management,* 1**,** 129-135.

Odame, H., Musyoka, P. and Kere, J. 2009. Kenya: Maize, Tomato, And Dairy. *Agribusiness And Innovation Systems In Africa***,** 89.

Pavelescu, F.-M. 2011. Some Aspects of the Translog Production Function Estimation. *Romanian Journal of Economics,* 32**,** 41.

Porcelli, F. 2009. Measurement of Technical Efficiency. A Brief Survey On Parametric And Non-Parametric Techniques. *Retrieved February,* 2**,** 2014.

Republic of Kenya (Rok), 2015. Human Development Report, 2015.Retrieved 20th January 2015 *Fromhdr.Undp.Org/Sites/All/Themes/.../Ken.Pd*

Sigei K. G., Ngeno, K.H., Kibe, M. A., Mwangi, M. and Mutai, C. M. 2014. Challenges And Strategies To Improve Tomato Competitiveness Along the Tomato Value Chain In Kenya. International Journal of Business And Management, 9, No. 9; 205-212.

Tefaye, W. 2014. Determinants of Technical Efficiency In Maize Production: The Case of Smallholder Farmers In Dhidhessa District of Illuababora Zone, Ethiopia. *Journal of Economics And Sustainable Development,* 5**,** 274-284.

Toenniessen, G., Adesina, A. and Devries, J. 2008. Building An Alliance For A Green Revolution In Africa. *Annals of the New York Academy of Sciences,* 1136**,** 233-242.