

ASSESSMENT OF TECHNICAL EFFICIENCY OF OPEN FIELD TOMATO 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. A two stage analysis using 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 (16 percent, 14 percent and 8 percent) had received credit, extension and agriculture support facilities. 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 smallholder 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 77200 tonnes 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 Kenya. In 2011, tomato production yielded a value of Ksh 12,354 million under a production area of 18,178 ha (Njoroge, 2014).

In Kenya, tomatoes are grown in most counties where altitude ranges from 1150m to 1800m above sea level (Odame *et al.*, 2009) . Nevertheless, the crop is mainly

produced in central region namely: Kirinyaga and Kiambu, Nyanza and Rift Valley regions. Despite Kiambu being a peri-urban area, it accounts for 5.2 percent (20972 tones) of the total tomato production in Kenya. The county also ranks sixth after Kirinyaga, Kajiado, Taita taveta, Meru and Bungoma in terms of tomato production. In 2013, a production value of Ksh 884 million under a production area of 930 hectares was recorded within the county (Geoffrey *et al.*, 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 to food security, employment, foreign exchange and it has been key in alleviation of poverty especially in rural areas where production is intensive (Geoffrey *et al.*, 2014). Despite this significant contribution of tomato production in the country's economy, productivity is still very low. In fact actual yield for all agriculture produces 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 also been 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 Sahara Africa 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 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 predicted to be greater than global averages (Bryan *et al.*, 2013).

In the course to increase agriculture productivity and adapt to climate change, modern technologies have been developed. These include biological and biotechnology approaches such as development of superior varieties, for example drought resistant varieties, pest-resistant and high-yielding varieties. Chemical technologies such as 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 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 in 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. Socioeconomic factors may have an influence on efficiency in agriculture

production. The objectives of the present study were therefore to estimate the technical efficiency of small scale tomato farmers in Kiambu and also underscored factors social economic factors influencing technical efficiency.

2.0 Materials and Methods

The study was conducted in Kiambu County, Kenya. Kiambu is in Central Kenya, a region known to contribute 5.2 percent (20972 tones) of the total tomato production in Kenya (Geoffrey *et al.*, 2014). A multi-stage 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 total of 240 tomato farmers using open field tomato production system were identified through an exploratory survey for each of the sampled sub counties. From this list, simple random sampling technique was used to sample farmers from each sub county. The total number of farmers sampled from each sub county was determined using proportional sampling technique. A total of 120 respondents was computed using a formula as provided by Naing *et al.* (2006). However, only 73 respondents were involved in the study because of missing and inappropriate responses (were removed as outliers). The target population of the study was of small scale tomato farmers using open field production system in Kiambu County and small scale farmers were defined as 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. Both technical and socioeconomic variables were measured which were yield of tomatoes in kilograms per acre, labour use in man-days, pesticide use per acre in litres, fertilizers use in kilograms per acre, education, experience, family size, farm size in acres, land under tomato production in acres , gender and age in years for the respondents.

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 variable multi-collinearity, heteroscedasticity and correlations nevertheless other functional forms were also tested.

4.0 Empirical Model Specification

The stochastic frontier analysis equation can be expressed as:

$$Y_i = f(X_i|\beta) e^{(v-u)} \dots \dots \dots (1)$$

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

$$\ln Y_i = \ln f(X_i|\beta) + V_i - U_i \dots \dots \dots (2)$$

where

Y_i = output level of i th farm, X = vector of inputs of i th farm, β = vector of unknown parameters, V_i = 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 = 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:

$$Y_i = \beta_0 X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} \dots X_5^{\beta_5} e^{(V_i - U_i)} \dots \dots \dots (3)$$

To enable the use of least square estimation procedure, the Cobb-Douglas function in 5 was transformed into a linear regression by expressing it in a logarithm form below:

$$\ln y_{(i)} = \beta_0 + \beta_1 (\ln X_1) + \beta_2 (\ln X_2) + \dots + \beta_5 (\ln X_5) + V_i + U_i \dots \dots \dots (4)$$

Where \ln = natural logarithm (to base e)

Y_i = 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 Fertilizers (kg)

X_4 = quantity of Pesticides (litres)

X_5 = tomato farm size (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:

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

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 have been 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 11 years as reported in the Republic of Kenya 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 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 (85 percent, 86 percent and 96 percent) did not receive any credit, extension and agriculture support facilities respectively. 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 kg 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 kg per acre for each of phosphorus and potassium. This all together gives a total of 480 kg per acre for nitrogen, phosphorus and potassium. Compared to the average of 211 kg 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 kg 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 kg of tomatoes harvested per acre. The observed yield is far low compared to the national average yield of 12280 kg per acre (Mwangi, 2012). The deviance in yield between the national and that observed in Kiambu County may be associated to presence of inefficiency within tomato production.

6.0 Technical Efficiency using SFA

To obtain the technical efficiency estimate, a stochastic frontier analysis approach was applied using different functional forms. The mean technical efficiency

estimated was 68 percent, 65 percent, 66 percent 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 and (Cobb Douglas and transcendental) production functions respectively. The determination of technical efficiency makes use 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	PARAMETER	TRANSLOG	COBB DOUGLAS	QUADRATI C	TRANSCEN DENTAL
INTERCEPT	β_0	- 8.318437* **	4.262312***	- 0.6237892	1.679091
LN FERT	β_1	2.360417* **	0.2953912 ***	2.202142*	0.439518
LN LABOR	β_2	2.831115* **	0.2928647**	.3292465* *	0.5895783 *
LN PESTICIDE	β_3	- 0.1674118 ***	0.1211908 *	- 0.4314952	0.2083839
LN SEED	β_4	0.3833992 ***	0.0756731	0.8291772 *	0.2082407 *
LNTOMATOLANDSIZ E	β_5	0.1679682 ***	0.1820911	0.0586254	0.7009491
LN FERTSQ	β_6	-		- 0.1841148	
LN LABORSQ	β_7	- .0315805* **			
LN PESTICIDESQ	β_8			0.0362146	
LN SEEDSQ	β_9	- 0.0634543 ***		- 0.0779599	
LNTOMATOLANDSIZ ESQ	β_{10}			- 0.0413594	
LN FERTILIZER- LN PESTICIDE	β_{11}	0.0478752 ***			
LN FERTILIZER- LN LABOUR	β_{12}	- 0.421959* **			
LN FERTILIZER- INTOMATOLANDSIZ E	β_{13}	0.00326** *			
LN SEED-LN LABOUR	β_{14}	0.0443174 ***			
TOMATO FARM SIZE	β_{14}				- 0.8698247
FERTILIZERS	β_{15}				- 0.0003739
PESTICIDES	β_{16}				9.12e-06
SEEDS	β_{17}				-0.000619

FERTILIZER_SEED	β_{18}				-1.48e-07
FERTILIZER	β_{19}				-1.64e-06
_LABOUR					
PESTICIDE_LABOUR	β_{20}				-3.46e-07
INEFFICIENCY					
MODEL					
CONSTANT	δ_0	0.5347291 ***	0.4636424 ***	.4748669* **	0.4886364 ***
EXPERIENCE	δ_1	0.0267729 ***	0.0234811 ***	0.0188855 **	0.0199977 ***
EDUCATION	δ_2	0.0140763 **	0.0131869 ***	0.0140221 ***	0.0131257 ***
FARM SIZE	δ_3	-0.0546*	-0.0474034 **	- 0.044579*	- 0.0438545 *
FAMILY_SIZE	δ_4	0.0214354	0.0245813 *	0.0287252 *	0.0235866
GENDER	δ_5	- 0.1675167 ***	-0.0785755 *	- .0882608* *	- 0.0893508 **
AGE	δ_6	- 0.0003649	-0.0010691	- 0.0010884	- 0.0009409
VARIANCE					
PARAMETERS					
SIGMMA 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		0.5801020 04	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		68.62	65.5	66.24	65.6
EFFICIENCY					

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

Hypothesis	L(H0)	L(H1)	Df	χ^2 calculated	χ^2 critical	Decision
H0=B6=B7...B14 =0	- 25.10	- 12.86	4	-3.90	9.49	Fail to reject H ₀

From the table 3 above, $H_0=B_6=B_7...B_{14} =0$ 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 multi collinearity (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.

Table 4: Technical efficiency using Cobb-Douglas production

Variable name	parameter	coefficients	Std.Error	Zvaleur	Pvalue	95% Conf interval
INTERCEPT	β_0	4.262312	0.899124 7	4.74	0.000	2.50006, 6.024564
LN FERTILIZE R	β_1	0.2953912	0.085999 1	3.43	0.001	0.126836,0. 463946
LN PESTICIDE	β_2	0.1211908	0.067712 6	1.79	0.073	-0.01152, 0.253905.
LN SEED	β_3	0.0756731	0.061295 9	1.23	0.217	- 0.04446,0.1 958109
LN LABOUR	β_4	0.2928647	0.146034 5	2.01	0.045	0.006642,0. 5790869
LN TOMATO LANDSIZE	β_5	0.1820911	0.117626 2	1.55	0.122	- 0.04845,0.4 126342
VARIANCE PARAMETER S						
SIGMA V	δV	0.086022				
SIGMA U	δU	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.

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

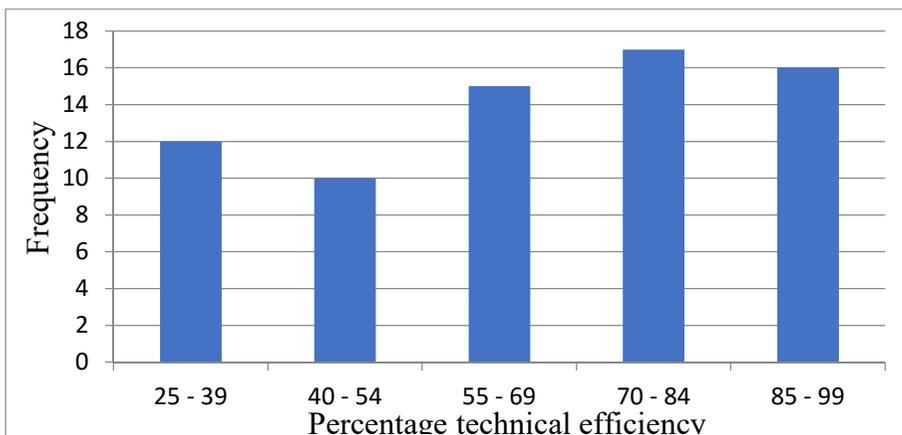


Figure 7: Technical efficiency and social economic characteristics

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 3.

Table 3: Technical efficiency and social economic characteristics

Variable name	parameter	coefficients	Std.Error	Zvale	Pvalue	95% Conf interval
CONSTANT	δ_0	0.4637534				.2318598,
			0.116113	3.99	0.000	.6956471
EXPERIENCE	δ_1	0.023475				.0087892,
			0.0073535	3.19	0.002	.0381609
AGE	δ_2	-0.00107				-.0059827,
			0.0024599	0.43	0.665	.0038427
EDUCATION	δ_3	0.013185				.004019,
			0.0045896	2.87	0.005	.022351
FAMILY_SIZE	δ_4	0.0245792				-.0051033,
			0.0148625	1.65	0.103	.0542618
GENDER	δ_5					-
						.1612044,0.0
FARMSIZEACR ES	δ_6	-0.0785805				040435
			0.0413712	-1.9	0.062	-.0948729,
		-0.0474003				.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 figure2.

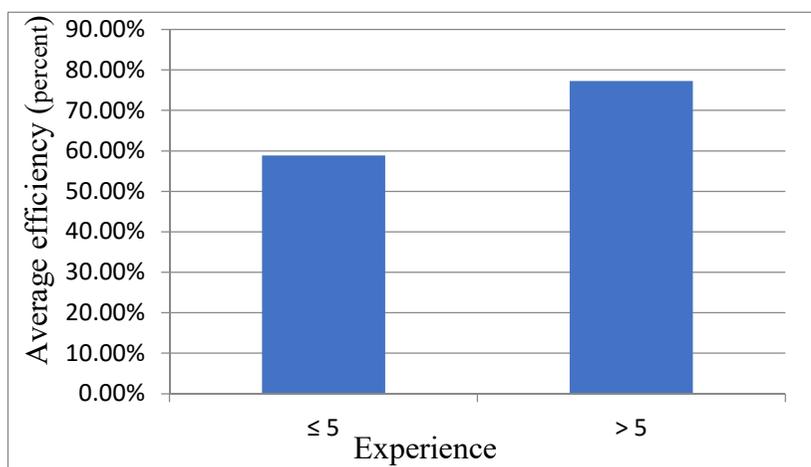


Figure 2: Experience and Average technical efficiency

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. This therefore implies that experience is key in uplifting production and hence the low technical efficiency observed in Kiambu County may be due to low experience by tomato farmers. 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 line with the findings of Tefaye (2014) and Donkoh *et al.* (2013) which also show that education negatively relates to technical inefficiency. The relationship between education and technical efficiency is presented in figure 3.

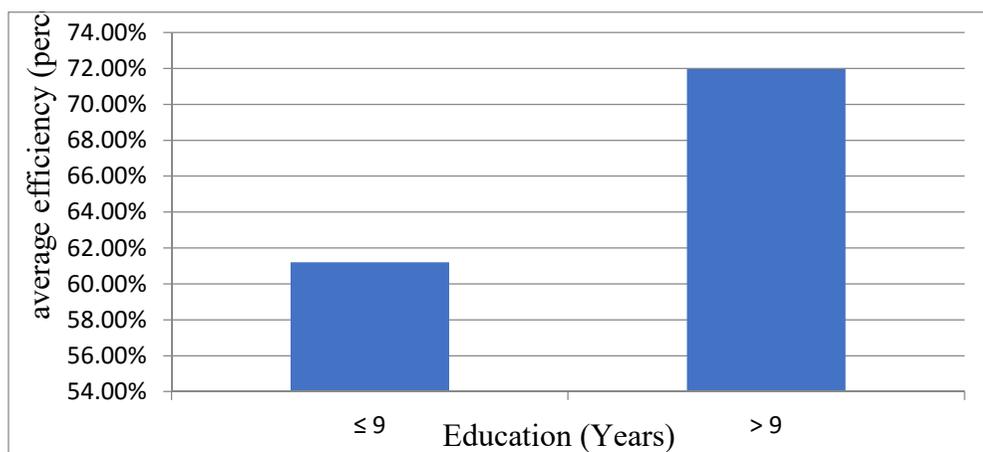


Figure 3: Education and average technical efficiency

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.

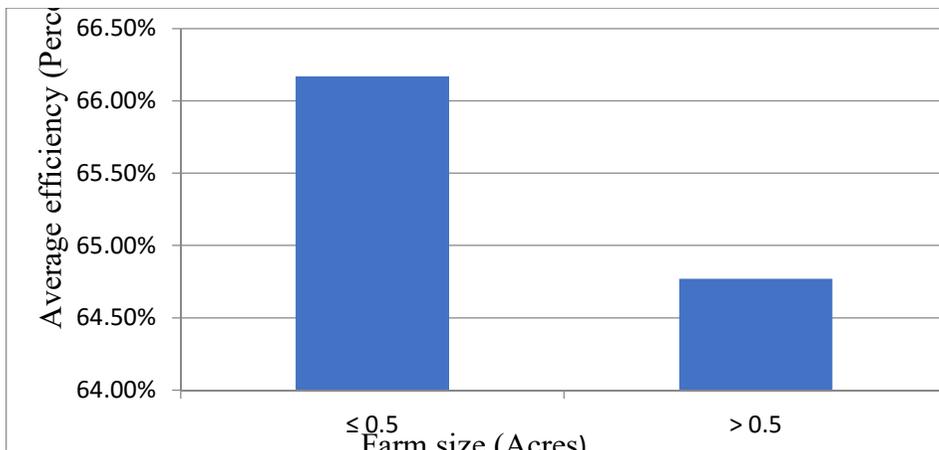


Figure 4: Farm size and average technical efficiency

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.

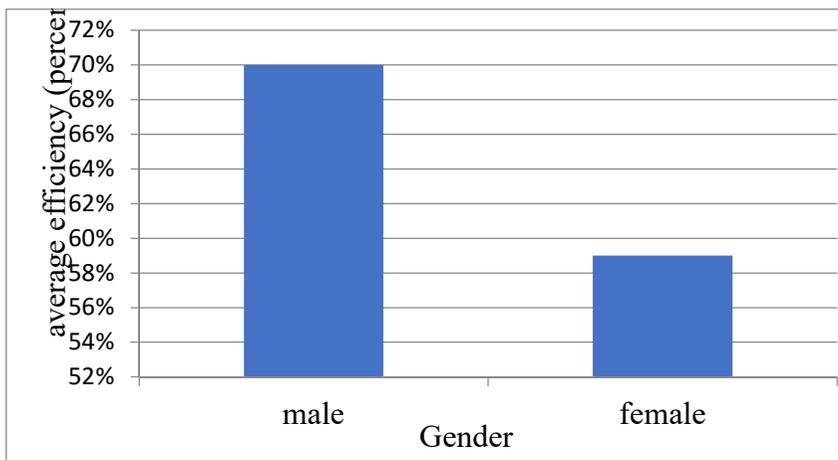


Figure 5: Gender and average technical efficiency

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 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 (16 percent, 14 percent and 8 percent) had received credit, extension and agriculture support facilities. 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.

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