To Examine the Determinants of Productivity of Small-Scale Holdings of Arabica Coffee and Its Supply Response in Kenya: A Case Study of Kiambu County

Samson M. Machuka
[1] Director of Monitoring and Evaluation Directorate;
Email: smmaseses@gmail.com,

Charles M.M. Ondieki
[2]Associate Professor at Multimedia University of Kenya and Chairman of TVET CDACC;
Email: charlesondieki@gmail.com,

***Abstract*—The main objective of this study was to investigate the determinants of productivity of coffee farms and its supply response in Kiambu County in Kenya. The study sought to assess how the combined use of coffee farm sizes, fertilizers and spray chemicals of the small scale farmers contributed to coffee productivity; how each of the three factors contributed individually to coffee productivity; how the supply response of coffee output varied based on coffee prices and input costs; and the trends in coffee output by the small scale farmers in the County. Data was collected from 125 farmers for the period 2004 to 2014. The study uses both fixed and random effects techniques to estimate the magnitude of the contribution of each factor to coffee productivity. A pooled regression analysis based on Cobb-Douglas and Nerlove models was conducted. The estimation results of the supply response based on the Nerlove model showed that coffee output in the current period varied significantly with changes in the coffee output in the previous period and its two-year lag. The long run price elasticity was estimated at 0.800. The estimation results also showed that prices of coffee were statistically insignificant in relation to coffee output. The estimation results also indicated that both the farm size and the quantity of triple 17 and CAN fertilizers used were positively and statistically significant in relation to the coffee output. This was, however, not the case for sumithion type of fertilizer. In addition, one acre of coffee farm increased coffee output by 1.418 kilograms. Further, the quantity of copper type of spray used was positively and statistically significant in increasing the coffee output. Based on the study, it is recommended that farmers need to increase the quantity usage of triple 17 fertilizer. It is also recommended that the government should subsidize the cost of fertilizers and spray chemicals. The Government is further recommended to apply the Linear GARCH model to forecast international coffee prices which can be disseminated to the farmers for informed decision making.**

***Keywords:* Productivity of Small-Scale Holdings; Arabica Coffee; Supply Response**

I. INTRODUCTION

A. Background Information

One of the earliest studies to explore the connection between farm size and productivity was carried out by Bardhan (1973) who found a negative relationship between output per acre and farm size in both rice and wheat fields in India. Studies on the subject of the inverse relationship between farm size and productivity flourished mostly because there is no really agreed upon explanation that has been given yet. Generally, the inverse relationship (IR) has not been fully accepted. Most studies therefore suggest further research should be carried out to examine the effect of farm size on total factor productivity. This study therefore, sought to examine the effect of farm size, types of fertilizer and spray chemical on total productivity of coffee production on one hand and the contribution of each factor of production to coffee production in Kiambu County in Kenya, and probably conclude this debate on IR.

Odhiambo *et al* (2004) established that most of the agricultural growth in Kenya is attributed to factor inputs of labour, land and capital. Mugweru (2011) found a positive relationship between price and coffee output in Kenya and statistically significant relationship with hectarage planted. Gathura (2013) established that marketing factors, finances, government policies and physical and human resources greatly affected coffee production. Bichanga (2013) found out that liberalization of the coffee sector resulted in decreased production of coffee

Coffee exports account for approximately five percent of all exports from Kenya. It is estimated that six million Kenyans are employed directly or indirectly in the coffee industry. Although the price of coffee increased from 220 US cents/kg in 2013 to 388 US cents/kg in March 2014 (Government of Kenya, 2014), this rise in price has not significantly changed the declining trend in smallholder production. On the contrary, in the same period larger farms faced with these price trends maintained steady production. This means that smallholder coffee farmers were faced with a unique and unfavourable set of economic and non-economic conditions that affected their supply response. On the average, 56% of coffee is produced by smallholders on individual plots of less than 2 hectares (or 5 acres). Table 1 below shows that coffee production trends have been largely influenced by the prevailing average prices in the international market.

TABLE 1: NATIONAL COFFEE AND AVERAGE AUCTION PRICES FROM 2000/01 TO 2013/14

YEAR	National Production (MT)	Average Prices in US$
2000/01	50,543	68.33
2001/02	51,895	77.66
2002/03	55,433	65.54
2003/04	48,431	83.21
2004/05	45,245	121.00
2005/06	48,835	135.06
2006/07	54,340	133.98
2007/08	43,000	177.23
2008/09	54,000	154.64
2009/10	40,000	218.41
2010/11	36,000	329.00
2011/12	49,960	225.83
2012/13	39,825	166.60
2013/14*	50,000	200.00

Source: Coffee Board of Kenya (various years)

It is noted from Table 1 that besides the supply response, farmers have been reactionary to price variations and therefore, they have not been on target. For example, when the price was highest at US$ 329 per MT in 2010/11 production was only 36,000 MT. In response to this high price production jumped to 49,960 MT in 2011/12, (an increase of more than 33% in one year) but the price dropped to US$225.83 per MT in 2012/13. This in turn led to a decline in production in 2012/2013 to 39,825 MT, a reduction of about 25%. This means that the farmers' response to coffee prices is reactionary and irrational, and always lags behind. This kind of supply response does not conform to long-term prospect of growing coffee in Kenya. This, therefore, poses a big problem to coffee farmers that need to be investigated and a solution found.

Previous studies have omitted years of weather shocks, while others used a dummy variable to account for weather impacts. These Nerlove-type models have generally found long-term elasticities to be higher than short-term elasticities (Renne, 1987). This study fills these gaps and also explores why we have had a decline of coffee production in Kenya during the study period between 2004 and 2014.

Rationally, goods and services are offered for sale in the market if the prevailing prices are high enough to make profits or break-even. According to the Nerlove model the relationship between supply and price is given in such a way that the response is highest soon after the price variation, which then reduces geometrically as lag increases.

Similarly, the Cobweb model is an economic model that shows why prices could be subjected to periodic variations in different types of markets. The model describes cyclical supply and demand in a market where the amount produced must be chosen before prices are observed. The expectations of producers on prices is based on the observations of the previous prices. The Cobweb model assumes that producers are extremely shortsighted. Assuming that farmers look back at the most recent prices in order to forecast future prices might seem very reasonable, but this backward-looking forecasting (which is called adaptive expectations) turns out to be crucial for the model's fluctuations. When farmers expect high prices to continue, they produce too much and therefore end up with low prices, and vice versa.

Njaramba (2011) found out that prices of coffee offered at the international market did not have any significant effect both in the long run and short run on the amount coffee supplied from Kenya. Mukuka (2012) found that Zambian coffee exhibits asymmetric short-run supply adjustments to long-run equilibrium such that production rises significantly after prices rise while changing little after prices fall.

Coffee productivity in Kenya has been declining for the three decades; the declining productivity is partly due to lower use of inputs, marketing problems, poor governance of cooperatives and international market conditions (Theuri, 2012). The area under coffee production decreased from 121,300 hectares in 2008/09 to 115,600 hectares in 2010/11 and to 109,800 hectares in 2012/13 (Government of Kenya, 2014). During this period coffee production decreased from 54,000 tons in 2008/09 to 36,300 tons in 2010/11 and increased slightly to 39,800 tons in 2013.

The underlying factors for dismal performance of coffee farms in Kenya are many and varied as alluded earlier. Bichanga and Mwangi (2013) attribute this to poor productivity of coffee farms, decline in application of inputs, poor farming practices and farmers' loss of confidence in management of coffee affairs. There are many other research studies that have been carried out to find the effects of agricultural inputs on coffee production (Nyangito, *et al*, 2004, Kirimi and Kithinji, 2011, Gathura, 2013).

Thus, an empirical investigation of productivity of coffee farms in Kiambu country bears an important implication for the development strategy of the coffee sub-sector in Kenya where farmers are found to be reasonably efficient; increases in productivity requires new inputs and technology to shift the production function upwards.

This study therefore, sought to investigate the individual contribution of farm size, fertilizers and spray chemicals to coffee productivity in Kiambu County which is the largest coffee producer in Kenya as per 2012/13 (CBK, 2014). Most of the earlier studies, which mainly used time series or cross sectional data separately, on coffee productivity in Kenya were not concerned with overall productivity of small holder farming. In this study, investigation of within and between the fixed and random effects of the identified variables on a time trend basis for the period between 2004 to 2014 as well as a cross zonal basis for the same period of time was also sought.

II. STATEMENT OF THE PROBLEM

More than twenty years since liberalization began, coffee production in Kenya has declined and remained depressed and this phenomenal forms the research problem in which we ask: Is this drop in coffee production as a result of liberalization or the factors of production had to do with this phenomenon? Liberalization has already been dealt with by Bichanga and Mwangi (2013) in their paper titled effects of liberalization on coffee production in Kenya. The research findings were that Liberalization of the coffee sector resulted in decreased production of coffee.

In their paper other reasons cited for the decline in coffee production included: decline in application of inputs (which are factors of production); poor farming practices; and farmers' loss of confidence in management of coffee affairs. There are many other research studies that have been carried out to find the effects of agricultural inputs on coffee production (Nyangito, et al, 2004, Gicuru Kirimi and Kithinji, 2011, Gathura, 2013). However, all the studies already carried have investigated the combined effect of all the factors of production on coffee.

The purpose of this study was therefore to investigate and determine the contribution of three factors of production to the productivity of coffee in Kenya. In particular, this study investigated and determined the individual contribution of farm size, fertilizers and spray chemicals to coffee productivity in Kiambu County which is the largest coffee producer in Kenya as per 2012/13 (CBK, 2014). There are many factors of production that affect production of coffee in Kenya: the main ones being labour, capital, farm size, fertilizers, chemical sprays, shade technology and agro-forestry.

Table 1.5 shows that coffee production trends have been largely influenced by the prevailing average prices in the international market.

TABLE 1.1: NATIONAL COFFEE AND AVERAGE AUCTION PRICES FROM 2000/01 TO 2013/14

YEAR	National Production (MT)	Average Prices in US$
2000/01	50,543	68.33
2001/02	51,895	77.66
2002/03	55,433	65.54
2003/04	48,431	83.21
2004/05	45,245	121.00
2005/06	48,835	135.06
2006/07	54,340	133.98
2007/08	43,000	177.23
2008/09	54,000	154.64
2009/10	40,000	218.41
2010/11	36,000	329.00
2011/12	49,960	225.83
2012/13	39,825	166.60
2013/14*	50,000	200.00

Source: Coffee Board of Kenya (various years)

It is noted from Table 1.5 that besides the supply response, farmers have been reactionary to price variations and therefore, they have not been on target. For example, when the price was highest at US$ 329 per MT in 2010/11 production was only 36,000 MT. In response to this high price production jumped to 49,960 MT in 2011/12, (an increase of more than 33% in one year) but the price dropped to US$225.83 per MT in 2012/13. This in turn led to a decline in production in 2012/2013 to 39,825 MT, a reduction of about 25%. This means that the farmers' response to coffee prices is reactionary and irrational, and always lags behind. This kind of supply response does not conform to long-term prospect of growing coffee in Kenya. This, therefore, poses a big problem to coffee farmers that need to be investigated and a solution found.

III. RESEARCH OBJECTIVES

The main objective of this study was to investigate the determinants of productivity of coffee farms and its supply response in the Kiambu County in Kenya. The specific objectives were to: (i) investigate and determine the combined contribution of farm size, type of fertilizer used and the type of chemical spray used to coffee productivity using Cobb-Douglas Production function; (ii) find out the individual contribution to coffee productivity by farm size, type of fertilizer used and the type of chemical spray used; (iii) estimate and analyze short run and long run supply response of coffee production by using Nerlove model; and (iv) explore the coffee production trend for the period 2004 to 2014 in Kiambu County.

IV. METHODOLOGY

A. Data

Data for the study was collected from 125 farmers from the three zones for the period 2004 to 2014. Sampling was computed according to the formula developed by Nassiuma (2000) given as: $n = \frac{Nc^2}{c^2 + (N-1)e^2}$, where ***n*** is the total sample size from the three coffee zones in Kiambu County, ***N*** is the total smallholders' coffee farmers in Kiambu County (which is about 32% of smallholdings in Kenya), ***c*** = coefficient of variation (≤ 30%) and ***e*** = error margin (≤ 5%). This formula enables one to minimize the error and enhance stability of the estimates.

The systematic approach was used to select the first farmer and skip the next three and interview the fourth one to ensure a wider and a fair selection of the farmers. The other expected sources of information included among others the following; existing materials on coffee and coffee production in Kenya and other countries, middle level institutions (the Coffee Board of Kenya, Kenya Planters Co- operative Union, various coffee societies and coffee factories countrywide, Ministry of Agriculture, Cooperative Bank of Kenya, and the Kenya National Bureau of Statistics). Due to time and resource constraints only 125 small scale farmers (47 from upper midland zone 1 across the county,46 from the upper midland zone 2 and 32 from upper midland zone 3 were interviewed. The stated sample size is considered appropriate for the research as it satisfies the conditions of the formula above. This sample size translates to 1375 observations when the same questionnaire is administered to each of the 125 farmers 11 times as the time period covered is 11 years.

A structured questionnaire was used to collect data from individual farmers and other stakeholders. The questionnaire was designed in a way that final coffee output figures were recorded based on all those that apply all the factors of production totally and also got those that applied some or all the factors and eventually compared overall results. Face to face interviews were also carried out to get information from the individual farmers and some Government officials.

B. Econometric Modelling

Consider a small holder farmer who produces coffee using a technology described by the production function: $Y(X_1, X_2, X_3) = AX_1^{b1}X_2^{b2}X_3^{b3}$

Where *Y* is the Coffee output, ***A*** denotes total factor productivity. ***X1*** stands for the coffee farm sizes in hectares, ***X2*** stands for the quantity of fertilizers used in a year; and ***X3*** denotes quantity of spray chemicals used in a year. The values given as ***b1, b2, b3*** are output elasticities obtained by trans logging the function into a generalized Cobb-Douglas production function form. Hence, by taking the logs of the above equation, it becomes:

$$lnY_t = lnA_t + b_1 lnX_{1t} + b_2 lnX_{2t} + b_3 lnX_{3t} + \mu_t,$$
$$t = 1, 2, 3, \dots \dots, n$$

Equation 2 would then be used to ascertain whether the production technology involved exhibits the following three features: If $b_1 + b_2 + b_3 = 1$, then the production technology exhibits constant returns to scale, meaning that doubling of inputs will double output. If $b_1 + b_2 + b_3 < 1$, then the production technology exhibits decreasing returns to scale, meaning that doubling of inputs will less than double the output If $b_1 + b_2 + b_3 > 1$, then the production technology exhibits increasing returns to scale, meaning that doubling of inputs will more than double the output.

To simplify the notation in equation 2, we define $y_t = \ln Y$, $x_t = \ln X$, then we can rewrite it as:

$$y_t = a_t + b_1 x_{1t} + b_2 x_{2t} + b_3 x_{3t} + \mu_t,$$

Since we are using panel data in our estimation, then equation (3) can be re-written as:

$$y_{it} = a_{it} + b_1 x_{1it} + b_2 x_{2it} + b_3 x_{3it} + \mu_{it},$$

If we write *it i it a* °a +μ , then we can re-write equation (4) as follows:

$$y_{it} = \alpha_i + b_1 x_{1it} + b_2 x_{2it} + b_3 x_{3it} + \mu_{it},$$

Here, we could interpret *I* a as capturing small holder farmer specific inputs such as management quality, which do not change over time. We then assume that

$$E(\mu_{it} \uparrow x_{1i}, x_{2i}, x_{3i}, \alpha_1, \dots., \quad \alpha_n) = 0$$

The model looks like a classical regression model, with two exceptions. First, there is a different intercept term for each smallholder farmer; and secondly, the conditioning variables are little different. The connection is even stronger if we define dummy variables

$$d_{it.j} = \left\{ \begin{smallmatrix} 0 \; if \; i=j \\ 1 \; 0 \; otherwise \end{smallmatrix} \right\}$$

Where, $x_{it} \equiv (x_{1it}, x_{2it}, x_{3it})', d_{it}$

$$d_{it,j} = \begin{cases} 0 \text{ if } & i = j \\ 1\ 0 & \text{otherwise} \end{cases}$$

$x_{it} \equiv (x_{1it}, x_{2it}, x_{3it})'$, $d_{it} \equiv (d_{1,it}, \ldots, d_{n,it})'$, $b \equiv (b_1, b_2, b_3)'$, and $\alpha = (\alpha_1, \ldots, \alpha_n)$ then

$E(y_{it}|x_i, \alpha) = x_{it}^{'} b + d_{it}^{'} \alpha$ ……. (7)

From equation (7), the fixed effect model can be written as:

$$E(y_{it}|X, \alpha) = x_{it}^{'} b + d_{it}^{'} \alpha$$

Where x_{it} is a $k \times 1$ vector of regressors (which does not include a constant), and d_{it} is a vector of dummy variables as defined above. Also, X is interpreted to contain all the regressors and dummy variables. If we assume that α_i are indentical and independently distributed with $E(\alpha_i|X) = 0$, $V(\alpha_i|X) = \sigma_\alpha^2$, and let us define $\psi_{it} = \alpha_i + \mu_{it}$, then the Random effect model can be written as:

$$y_{it} = x_{it}^{'} + \psi_{it}, \qquad i = 1, \ldots, n; t = 1, \ldots, T \quad (9)$$

Fixed effects regression is used to control for omitted variables that differ between the coffee farmers but are constant over the time period 2004 to 2014. However, some omitted variables may be constant over the given time period but vary between the coffee farmers. Other variables may be fixed between the coffee farmers but vary over time. One can include both types of variables which vary between coffee farmers and also over time by using random effect model.

C. Nerlove Model

This study examined the supply response of coffee farms by using the Nerlove model. In its simplest version Nerlove's model consists of the three equations:

$$A_{it}^* = \alpha_0 + \alpha_1 P_{it}^* + \mu it$$

$$A_{it}^* = P_{i(t-1)}^* + \beta(P_{i(t-1)} - P_{i(t-1)}^*)$$

$$A_{it} = A_{i(t-1)} + \gamma(A_{it}^* - A_{i(t-1)})$$

Where ***At*** and ***At**** are actual and desired area under cultivation (or sometimes output or yield) at time ***t***, ***Pt*** and ***Pt**** are actual and expected price at time ***t***, and ***β*** and γ are the expectation and adjustment coefficients, respectively. Elimination of the unobservable variables ***A****and ***P**** leads immediately to the reduced form

$$A_{it} = b_0 + b_{1it} P_{i(t-1)} + b_{2it} A_{i(t-1)} + b_{3it} A_{i(t-2)} + vit$$

with

$b_0 = \alpha_0 \beta \gamma, b_{1it} = \alpha_1 \beta \gamma, b_{2it} = (1-\beta) + (1-\gamma), b_{3it} = -(1-\beta)(1-\gamma)$and

$v_{it} = \gamma(\mu_{it} - (1-\beta)\mu_{i(t-1)}\alpha$

from which the key parameter $\alpha_1$may be retrieved by means of the identity

$\alpha_1 = b_{1it}/(1 - b_{2it} - b_{3it})$ the long-run price elasticity ε is then usually calculated as

$$\varepsilon = \alpha_1 \frac{\bar{P}}{\bar{A}} = \frac{b1it}{1\text{-}b2it\text{-}b3it} \frac{\bar{P}}{\bar{A}}$$

Where $\bar{\rho}$ and $\bar{A}$, represent historical mean of prices and acreage under cultivation, respectively

V. RESULTS AND DISCUSSION

A. Determinants of Productivity of coffee

1) Unit Root Results

Before estimating our models, a panel unit root test was performed in order to establish whether the variables were stationary. Since the data used was a balanced panel, the stationarity tests conducted were Levin-Lin-Chu test (LLC), Harris-Tsavalis test (HT) and the Breitung test. The three tests (LLC, HT and Breitung) were done at levels, at first difference and at levels with time trend included. Table 1 gives the summary of the unit root test based on the Breitung Test.

TABLE 1: BREITUNG PANEL UNIT ROOT TESTS

Lambda Statistic			
Variable	**Levels**	**First difference**	**Levels with time trend**
Coffee output	-3.2269	2.3269*	0.2371*
Farm size Acres	-3.8264	5.4240*	3.7927*
Fertilizer Quantity KG	-9.1088	2.4322*	1.7183*
Spray Quantity litres	-11.8208	1.6079*	1.8775*

Source: Field Data (2016)

** denotes statistical significance at the 5 percent level*

Table 1 shows that we cannot reject the null hypothesis of a unit root at the 5% level. However, after conducting the first difference of the variables they attained stationarity. Specifically, all the variables had time specific effects since after de-trending the variables attained stationarity. Similar, results were revealed when the LLC and HT tests were conducted. Statistically speaking, estimation of a fixed effects model is always a reasonable thing to do in panel data estimation. This is because fixed effects models give consistent results such that as the sample size increases indefinitely the estimated parameters converge to their true values. The fixed effects models may, however, not be the most efficient (have minimum variance) model to run. Since, studying the entire population is expensive and time-consuming, consistency ensures that the sample being surveyed represents reality of what is taking place in the entire population, while efficiency ensures there are minimal variations between observed characteristics under investigation. Random effects will give better P-values (higher chances of finding that various policy options do influence the coffee output) as they are a more efficient estimator, so one should run random effects if it is statistically justifiable to do so.

2) Estimation Results

The data used in this study is panel data. Two models were estimated namely the fixed effects and random effects model. Fixed effects regression was used to control for omitted variables that differ between the coffee farmers but are constant over the time period 2004 to 2014. However, some omitted variables may be constant over the given time period but vary between the coffee farmers. Other variables may be fixed between the coffee farmers but vary over time. One can include both types of variables which vary between coffee farmers and also over time by using random effect model. Hence we also estimated the random effects model.

The main advantage of fixed effects models is that it gives consistent results such that as the sample size increases indefinitely the estimated parameters converges to their true values. The fixed effects models may, however, not be the most efficient (have minimum variance) model to run. Since, studying the entire population is expensive and time-consuming, consistency ensures that the sample being surveyed represents reality of what is taking place in the entire population, while efficiency ensures there are minimal variations between observed characteristics under investigation. However, the random effects model gives better P-values (higher chances of finding that various policy options do influence the coffee output) as they are a more efficient estimator, so one should run random effects if it is statistically justifiable to do so. The results for the random and fixed effects model are presented in table 2 columns 1 and 2.

3) Results of Fixed Effects

As can be seen in table 2 below results for fixed effects model show that holding all factors constant, an increase in farm size by1% increases coffee output by 54%. Similarly, an increase in fertilizer quantity by 1% increases coffee output by 27%. An increase in spray quantity by 1% also increases coffee output by 2%. The constant under this case is at 5.

4) Results of Random Effects

As can be seen in table 2 results for random effects show that holding all other factors constant, an increase in farm size by 1% increases coffee output by 35%. Similarly, an increase in fertilizer quantity by 1% increases coffee output by 28%. An increase in spray by 1% increases coffee output by 2%. The constant under this case is at 5. In order to choose between fixed effects and random effects models, we conducted the test suggested by Hausman (1978). The fixed effects model assumes individual heterogeneity, while the random effects model assumes that the variations are probabilistic. Under the Hausman (1978) test, the null hypothesis is that the coefficients estimated by the efficient random effects estimator are the same as the ones estimated by the consistent fixed effects estimator. The Hausman (1978) test, therefore, checks a more efficient model against a less efficient but consistent model to make sure that the more efficient model also gives consistent results. A summary of the Hausman (1978) test results are presented in table2.

TABLE 2: HAUSMAN TEST

	Random Effects Model	Fixed Effects Model	Difference
Ln Coffee output			
Ln Farm size Acres	0.349*	0.541*	0.192
Ln Fertilizer Quantity KG	0.277*	0.272*	-0.005
Ln Spray Quantity litres	0.021	0.018	-0.003
Constant	5.083*	5.065*	
Number of Observations	593	593	
R-Squared (R^2)			
Within	0.1027	0.1054	
Between	0.0759	0.0731	
Overall	0.1852	0.1553	
F-Statistic		18.78	
P-Value		0.0000	
Chi-Square Statistic (X^2)		63.83	3.06
P-Value	0.0000		0.3819

Source: Field Data (2016)

The test results show that the Chi-square (X^2) statistic for the difference was 3.06, with a corresponding p-value of 0.3819. Since this p-value (0.3879) was larger than the critical value of 0.05, the null hypothesis that the differences in the coefficients are not systematic was rejected. This means that the preferred model was the random effects model. The empirical results presented in the subsequent sections are based on the random effects model.

5) Coffee Productivity Using Pooled OLS Regression Model with Dummy Variables

The results presented in Table3 show that the quantity of CAN fertilizer used is positively and statistically significant in relation to coffee output. Hence the quantity of coffee output is more when either triple 17 or CAN type of fertilizer is used compared to failure to use any fertilizer in coffee production. The table also illustrates that the quantity of copper type of spray used was positively and statistically significant in increasing the coffee output. However, the table illustrates that the quantity of *sumithion* type of fertilizer used is negatively but statistically insignificant in relation to coffee output. Thus, the coffee output realized increases with the increase in the quantity of copper spray used, though the coffee output is the same irrespective of whether a farmer used *sumithion* type of spray or didn't use any spray at all.

Results presented in Table 3 further shows that the level of primary education and secondary education is positively and statistically significant in influencing coffee output production. Though, statistical significance was deduced at the 10 per cent level of significance. However, the level of post -secondary education was positively but statistically insignificant in relation to coffee output. Hence, farmers who had attained primary and secondary education realized more output compared to those with no education. This shows that attaining basic education (primary and secondary education level) by the farmers is essential for the coffee farmers to enhance their coffee productivity. These results are similar to the works of Bagamba *et al* (2003) who found that those who attained higher levels of Education withdrew their labour from banana farming in Uganda and sought other opportunities elsewhere in the formal economy

TABLE 3: COFFEE PRODUCTIVITY USING POOLED OLS REGRESSION MODEL WITH DUMMY VARIABLES

Ln coffee output	**Coefficient**	**p-value**
Ln farm size in acres	0.236*	0.000
No fertilizer used	**Reference**	
Ln quantity of 17 17 17 type of fertilizer	0.071*	0.028
Ln quantity of CAN type of fertilizer	0.082*	0.000
No spray used	**Reference**	
Ln quantity of copper type of spray	0.270*	0.010
Ln quantity of sumithion type of spray	-0.110	0.210
No education	**Reference**	
Primary education	0.436**	0.069
Secondary education	0.395**	0.085
Post-secondary education	0.286	0.238
Year 2004	**Reference**	
Year 2005	-0.045	0.818
Year 2006	-0.209	0.298
Year 2007	-0.259	0.191

Year 2008	-0.151	0.452
Year 2009	-0.102	0.599
Year 2010	-0.192	0.335
Year 2011	-0.115	0.555
Year 2012	-0.085	0.662
Year 2013	-0.229	0.241
Year 2014	-0.391**	0.052
UM1 Zone	**Reference**	
UM2 zone	1.061*	0.000
UM3 Zone	0.643	0.000
Constant	4.943*	0.000
F-Statistic (20,572)	11.99*	0.000
R-Squared	0.4953	
Adjusted R-Squared	0.4707	
Testparm for the years chi-square (10) = 12.79 P-Value=0.2354		
Testparm for the zones chi-square (2) = 9.96 P-Value = 0.0069		

Source: Field Data (2016)

6) Combined Contribution of Inputs to Coffee Productivity

Table 4 shows the estimation results and derivation of output elasticities of the three factors of coffee production using the Cobb-Douglas production function for all the years under review. The estimation results give the chi-square Wald test for joint significance with statistic values of 1.10, 78.13, 15.54 and 63.83 for UM1, UM2, UM3 and all zones combined, respectively. The associated p-values for the Wald chi-square statistic shows that the variables included in the model for explaining coffee productivity are all jointly significant for zone UM2, UM3, and all zones combined. However, the explanatory variables in UM1 zone are not jointly significant in explaining coffee productivity. The estimated parameter for the overall R-squared shows that the explanatory variables included in the model account for 47.29% of the variations in coffee output in UM1 zone. Similarly, the explanatory variables in the model account for 58.21%, 46.16% and 52.52% of the variations in coffee output in UM2, UM3 and all zones combined, respectively. This means that the model adequately explains the changes in coffee productivity.

7) Individual Contribution to Coffee Productivity by Inputs

The individual contribution by the inputs used to coffee productivity was assessed by taking the exponents of the linear-log function. The results are summarized in Table 5. Upon taking the exponents of the regression coefficients and also considering the statistical significance, we deduce that an increase in farm size by one acre increases the coffee output realized by 1.762 kilograms and 1.446 kilograms in zones UM2 and UM3 respectively. In addition, one acre of coffee farm increases coffee output by 1.418 kilograms for all combined zones in Kiambu County. Similarly, an additional use of one kilogram of fertilizer increases the coffee yield by 1.544 kilograms and 1.294 kilograms in UM2 and UM3 zones respectively. Moreover, an increase in fertilizer by one kilogram increases coffee output by 1.320 kilograms. However, the coefficient on the quantity of spray used was not statistically significant. Hence, an increase of spray quantity usage by one litre does not lead to an increment in coffee yield implying that the yield in coffee is the same irrespective of the quantity of spray used. The total factor productivity for zone UM1 is 452.138, 82.062 for zone UM2, 199.956 for zone UM3 and 161.245 for all the zones combined in Kiambu County.

When assessing the individual contribution of coffee productivity by inputs for various years, the findings show that farm size in acres was positively and significantly related to coffee output only the year 2013, where an increase of farm size by one acre leads to an increase in the yield of coffee productivity by 1.781Kgs. The quantity of compound (17 17 17) fertilizer used in the years 2005, 2006, and 2008 was positively and statistically significant at the 5% level of significance in relation to coffee productivity.

Further analysis indicates that an additional usage of triple 17 type of fertilizer by one kg contributes to a rise in coffee output by 1.784 Kgs in 2005, 1.683 Kgs in 2006 and 1.204 Kgs in 2008. In addition, the quantity of CAN fertilizer in Kgs was positively and statistically significant in influencing coffee productivity for the years 2009, 2010, 2011 and 2012. Specifically, an increase of the application of CAN fertilizer by one Kg leads to an increase in coffee output by 1.186Kgs in 2009, 1.111Kgs in 2010, 1.174Kgs in 2011 and 1.113Kgs in 2012. The quantity of copper spray type used in litres was positively and statistically significant in influencing coffee output in the year 2007, 2008, 2011 and 2012. In particular, an increase in quantity of copper spray by one litre led to an increase in coffee output by 2.475Kgs in 2007, 2.674Kgs in 2008, 1.800Kgs in 2011 and 1.804Kgs in 2012. However, the quantity of *sumithion* spray used, was not significantly related to the output of coffee for all the years considered

TABLE 5: INDIVIDUAL CONTRIBUTION OF INPUTS TO COFFEE PRODUCTIVITY

	UM1 zone	UM2 zone	UM3 zone	All Zones
Ln Coffee output	Exponent (Coefficient)	Exponent (Coefficient)	Exponent (Coefficient)	Exponent (Coefficient)
Ln Farm size Acres	0.930	1.762*	1.446**	1.418*
Ln Fertilizer Quantity KG	1.013	1.544*	1.294*	1.320*
Ln Spray Quantity litres	0.911	1.029	1.073	1.021
Constant	452.138*	82.062*	199.956*	161.245*
Chi-Square (3)	1.10	78.13*	15.54*	68.83*
Within R-Squared	0.3852	0.4917	0.3931	0.5427
Between R-Squared	0.3561	0.3930	0.4561	0.5159
Overall R-Squared	0.47290	0.5821	0.4616	0.5252

Source: Field Data (2016)

B. Supply Response of Coffee Production Using the Nerlove Model

In this section, we present the estimation results of the Nerlove model based on the price of coffee. All the Nerlove model results were based on panel data covering all the three coffee zones; UM1, UM2 and UM3. The underlying assumption is that farmers take keen interest on variations in output prices and that such changes affect their production decisions, hence the supply response. A variant to this is that changes in prices of inputs, in this case fertilizers and sprays enter into the farmers' production thus affecting supply. In undertaking the analysis, the study first conducted a pooled OLS regression model for supply response of coffee production before estimating the Nerlove model for the respective zones using the random effects model. This was necessary to assess whether or not the supply response of coffee production differed across zones and years. Table 2 below gives a summary of the estimation results.

TABLE 2: SUPPLY RESPONSE OF COFFEE PRODUCTION USING POOLED OLS REGRESSION

Coffee output at time t (A_t)	**Coefficient**	**P-value**
Price of Coffee per Kg in Kshs (P_{t-1})	7.707	0.611
Coffee output at time t-1 (A_{t-1})	0.831*	0.000
Coffee output at time t-2 (A_{t-2})	0.058	0.274
Year 2004	**Reference**	
Year 2005	373.076	0.712
Year 2006	116.202	0.881
Year 2007	198.714	0.801
Year 2008	141.303	0.855
Year 2009	143.819	0.849
Year 2010	51.467	0.943
Year 2011	265.512	0.720
Year 2012	Omitted	
Year 2013	60.545	0.897
Year 2014	56.989	0.906
UM1 Zone	**Reference**	
UM2 zone	127.878	0.452
UM3 Zone	308.805*	0.030
Constant	-363.257	0.758
F-Statistic (14,1011)	54.50*	0.000
R-Squared	0.4301	
Adjusted R-Squared	0.4222	
α_1	68.977	
α_0	-3251.030	
ε	1.977	
Testparm for the years F(9, 1011)	0.200	0.994
Testparm for the zones F(2, 1011)	2.450**	0.087

Source: Field Data (2016)

The estimation results presented in Table 2 shows that the estimated model had an F-statistic value of 54.50 with a corresponding P-value of 0.0000. This illustrates that the included variables in the model are jointly significant in explaining the variations of coffee output. The adjusted R-square of 0.4222 shows that up to 42.22% of changes in coffee output are explained by the variables included in the model.

From the results presented in Table 2 and upon including the price of coffee per Kg in Kshs gives bo = -363.26, b1 =7.707, b2 = 0.831 and b3 = 0.058. This means that α1 = 68.977 and α0 = -3251.030. Hence, based on the supply response from pooled OLS regression, the coffee output in the current time period varies significantly with changes in the coffee output in the previous one year. The estimation results yield a long run price elasticity of 1.977. The computed price elasticity of 1.977 implies that a unit change in the price of coffee leads to 1.977 changes in coffee output.

After conducting the supply response using the pooled OLS regression model, a joint parameter test for the years and the zones was conducted. The results presented in Table 2 gives F-test statistic of 0.200 and a p-value of 0.994 for the year variable. The F-statistic, which is the coefficient of joint determination, is statistically insignificant. This means that there was no statistically significant difference in the coffee output realized by the coffee farmers in Kiambu County across the years. In respect to the zones, the F-statistic was 2.45 with a p-value of 0.087. According to the estimation results, the joint inclusion of zones was statistically insignificant at the 5% level. It was, however, statistically significant at the 10% level of significance. This means that there was no statistically significant difference in output across three zones, if tested at 5% significance level. Statistically significant differences in output between the zones could only be sustained if the test was conducted at the 10% significance level.

It is evident from the results presented in Table2 that the parameter test for joint inclusion of the years' variables in the supply response model is not statistically significant. The results presented in Table2, however, show that the parameter test for the joint inclusion of the zones in the supply response model was statistically significant at the 10% level of significance. Consequently, the analysis of the Nerlove model using the random effects model will not incorporate the year variables but will include each of the three zones, and an analysis of the three zones combined. Table 3 gives a summary of the results supply response of coffee production based on estimation of the Nerlove model for UM1 zone. The variable of importance is coffee prices.

TABLE 3: SUPPLY RESPONSE OF COFFEE PRODUCTION USING NERLOVE MODEL FOR ZONE UMI

Coffee output at time t (A_t)	Coefficient	P-value
Price of Coffee per Kg in Kshs (P_{t-1})	1.335	0.356
Coffee output at time t-1 (A_{t-1})	0.644*	0.000
Coffee output at time t-2 (A_{t-2})	0.169*	0.000
Constant	52.662	0.417
Chi-Square (3)	713.35	0.000
Within R-Squared	0.0211	
Between R-Squared	0.9662	
Overall R-Squared	0.6650	
α_1	7.139	
α_0	281.615	
ε	0.409	

Source: Field Data (2016)

The estimation results presented in Table3 gives a chi-square Wald test for joint significance with statistic values of 713.35 for UM1 zone. The associated p-value of 0.0000 for the wald chi-square statistic shows that the variables included in explaining coffee productivity are jointly significant in UM1 zone. Furthermore, the overall R-squared value of 0.6650 shows that the explanatory variables included in the model account for 66.50% of the variation in coffee output in UM1 zone.

From the reduced form equation of the Nerlove model and upon including the price of coffee per Kg in Kshs for zone UM1, the estimation results give a bo = 52.662, b1 = 1.335, b2 = 0.644 and b3 =0.169. Hence, based on equation α1 = b1/ (1 – b2 – b3), α1 =7.139. After solving the equation for b0 and b1, gives α0 =b0/b1α1=281.615. The implication is that based on the Nerlove model, coffee output in the current time period varies significantly with changes in the coffee output in the previous one year and also in the coffee output in the previous two years.

Based on the formula (the mean price of fertilizers/the average coffee output). The long run price elasticity, which gives the degree of responsiveness of changes in coffee output as a result of changes in the price of coffee, is 0.409. Thus a unit change in the price of coffee leads to a 0.409 change in coffee output. If the cost-based assumption is used and the nerlove model is fitted with the cost of inputs: fertilizers and spray, then the estimation results for UM1 zone is as illustrated in Table 4.

The results presented in Table 4 gives chi-square wald tests for joint significance with statistic values of 719.96 and 720.51 for UM1 zone when cost of fertilizer and cost of spray were used, respectively. The associated p-values of 0.0000 for the wald chi-square statistic shows that the variables included in the model are jointly significant in explaining coffee production in UM1 zone. Furthermore, the overall R-squared value of 0.6644 shows that the explanatory variables included in the model account for 66.44% of the variation in coffee output in UM1 zone when cost of fertilizer was used. Similarly, the overall R-squared of 0.6689 deduced from the estimation when cost of spray is used implies that 66.89% of the variations in coffee output in UM1 zone is explained by the model.

TABLE 4: SUPPLY RESPONSE OF COFFEE PRODUCTION USING NERLOVE MODEL FOR ZONE UMI

Variable	**If Cost of fertilizer is used**		**If Cost of spray is used**	
Coffee output at time t (A_t)	**Coefficient**	**P-value**	**Coefficient**	**P-value**
Cost of Fertilizer used in Kshs (P_{t-1})	0.002	0.718		
Cost of Spray used in Kshs (P_{t-1})			0.027*	0.021
Coffee output at time t-1 (A_{t-1})	0.641*	0.000	0.638*	0.000
Coffee output at time t-2 (A_{t-2})	0.168*	0.000	0.170*	0.000
Constant	96.366*	0.012	64.789**	0.095
Chi-Square (3)	719.96*	0.000	720.51	0.000
Within R-Squared	0.0209		0.0238	
Between R-Squared	0.9663		0.9647	
Overall R-Squared	0.6644		0.6689	

Source: Field Data (2016)

The estimation results presented in Table 4 indicates that the reduced form equation of the Nerlove model, and upon including the cost of fertilizers for zone UM1 without incorporating the cost of spray gives bo = 96.366, b1 = 0.002, b2 = 0.641 and b3 = 0.168. Hence, based on equation α1 = b1/ (1 – b2 – b3), α1 =0.010. After solving the equation for b0 and b1, gives α0 =b0/b1α1=504.534. The implication is that coffee output in the current time period varies significantly with changes in the coffee output in the previous one year and also in the coffee output in the previous two years. These results are consistent with those reported in Table 3, which uses price of coffee as the variable of significance. Based on the formula

$$\varepsilon = \alpha_1 \frac{\rho}{A} = \varepsilon_1 \left(\frac{the\ mean\ price\ of\ fertizers}{the\ average\ coffee\ output}\right),$$

the long run price elasticity, which gives the degree of responsiveness of changes in coffee output as a result of changes in the cost of fertilizer inputs, is 0.080. Thus a unit change in the cost of fertilizer leads to a 0.080 change in coffee output. However, when the cost of spray is included only in the reduced form equation of the Nerlove model in UM1 zone, then bo = 64.789, b1 = 0.027, b2 = 0.638, b3 = 0.170, α1 =0.141 and α0 = 337.443. On applying the parameter estimates to the formula, it yields a long run price elasticity of 0.331. This indicates that a unit change in spray input contributes to a 0.331 change in coffee output.

Table 5 gives a summary of the results for supply response of coffee production for Zone UM2 using the Nerlove model. It gives the estimation results when the Nerlove model is fitted with price of coffee. The results presented in Table 5 gives a chi-square Wald test for joint significance with statistic values of 532.61 for UM2 zone. The associated p-value of 0.0000 for the Wald chi-square statistic shows that the variables included the model are jointly significant in explaining coffee productivity in UM2 zone. The estimated overall R-squared value is 0.5894. This shows that the explanatory variables included in the model account for 58.94% of the variation in coffee output in UM2 zone.

TABLE 5: SUPPLY RESPONSE OF COFFEE PRODUCTION USING NERLOVE MODEL FOR ZONE UM2

Coffee output at time t (A_t)	**Coefficient**	**P-value**
Price of Coffee per Kg in kshs (P_{t-1})	-0.398	0.929
Coffee output at time t-1 (A_{t-1})	0.668*	0.000
Coffee output at time t-2 (A_{t-2})	0.108*	0.046
Constant	346.706*	0.032
Chi-Square (3)	532.61*	0.000
Within R-Squared	0.0540	
Between R-Squared	0.9870	
Overall R-Squared	0.5894	
α_1	-1.777	
α_0	1547.795	
ε	-0.032	

Source: Field Data (2016)

From the reduced form equation of the Nerlove model and upon including the price of coffee per Kg in Kshs for zone UM2 gives bo = 346.706, b1 =-0.398, b2 = 0.668 and b3 = 0.108 and hence α1 =-1.777 and α0 =1547.795. Hence, based on the Nerlove model, the coffee output in the current time period varies significantly with changes in the coffee output in the previous one year and also in the coffee output in the previous two years. This yields a long run price elasticity of -0.032 showing that a unit change in the price of coffee leads to -0.032 changes in coffee output.

Table 6 gives the estimation results of the Nerlove model for UM2 zone based on cost of inputs. The estimation results give chi-square Wald tests for joint significance with statistic values of 551.35 if cost of fertilizer is used and a statistic of 534.91 if cost of spray is used. The associated p-values of 0.0000 for the Wald chi-square statistic shows that the variables included in the model are jointly significant in explaining coffee production in UM2 zone. The Overall R-squared is 0.5978 for the model that considers the cost of fertilizer and 0.5905 for the model that considers the cost of spray. The estimated values of the overall R-Squared shows 59.78% of the variations in coffee output in UM2 zone is explained by the explanatory variables included in the model that considers the cost of fertilizer. The statistic of 0.5905 in the model that includes the cost of spray implies that 59.05% of the variations in coffee output in UM2 zone is explained by the explanatory variables included in the model.

TABLE 6: SUPPLY RESPONSE OF COFFEE PRODUCTION USING NERLOVE MODEL FOR ZONE UM2

Variable	**If Cost of fertilizer is used**		**If Cost of spray is used**	
Coffee output at time t (A_t)	**Coefficient**	**P-value**	**Coefficient**	**P-value**
Cost of Fertilizer used in Kshs (P_{t-1})	0.019*	0.007		
Cost of Spray used in Kshs (P_{t-1})			0.009	0.328
Coffee output at time t-1 (A_{t-1})	0.626*	0.000	0.658*	0.000
Coffee output at time t-2 (A_{t-2})	0.094**	0.079	0.110*	0.041
Constant	268.509*	0.004	312.765*	0.001
Chi-square (3	551.35*	0.000	534.91	0.000
Within R-Squared	0.0684		0.0547	
Between R-Squared	0.9768		0.9851	
Overall R-Squared	0.5978		0.5905	

Source: Field Data (2016)

The results presented in Table 6 indicates that from the reduced form equation of the Nerlove model and upon including the cost of fertilizers for zone UM2 without incorporating the cost of spray gives bo = 268.509, b1 = 0.019, b2 = 0.626 and b3 = 0.094 and hence α1 =0.068 and α0 =958.961. Hence, based on the Nerlove model, coffee output varies significantly as a function of changes in the previous year's cost of fertilizers and changes in the previous year's cost of spray chemicals. In addition, the coffee output in the current time period varies significantly with changes in the coffee output in the previous one year and also in the coffee output in the previous two years. This yields a long run price elasticity of 0.356 showing that a unit change in the cost of fertilizer leads to 0.356 changes in coffee output. However, when the cost of spray was included only in the reduced form equation of the Nerlove model in UM2 zone bo = 312.765, b1 = 0.009, b2 = 0.658 and b3 = 0.110. Hence, α1 =0.039 and α0 =1348.125. This yields a long run price elasticity of 0.094 which indicates that a unit change in spray input contributes to a 0.094 change in coffee output.

Table 7 gives a summary of the results for supply response of coffee production for Zone UM3 using the Nerlove model; the computed chi-square Wald test for joint significance has a value 131.47. The associated p-value for the Wald chi-square statistic is 0.0000. This shows that the variables included the model are jointly significant in explaining coffee production in UM3 zone. The overall R -squared has a value of 0.3376. This shows that the explanatory variables included in the model account for 33.76% of the variation in coffee output in UM3 zone

TABLE 7: SUPPLY RESPONSE OF COFFEE PRODUCTION WITH NERLOVE MODEL FOR ZONE UM3

Coffee output at time t (A_t)	**Coefficient**	**P-value**
Price of Coffee per Kg in kshs (P_{t-1})	6.357	0.506
Coffee output at time t-1 (A_{t-1})	1.6090*	0.000
Coffee output at time t-2 (A_{t-2})	-0.22800	0.321
Constant	-447.14600	0.268
Chi-Square (3)	131.4700*	0.000
Within R-Squared	0.1699	
Between R-Squared	0.7281	
Overall R-Squared	0.3376	
α_1	-16.6850	
α_0	1173.6120	
ε	-0.4530	

Source: Field Data (2016)

From the reduced form equation of the Nerlove model and upon including the price of coffee in the previous one year for zone UM3 without gives bo =-447.15, b1 =6.357, b2 = 1.609 and b3 =-0.228. Hence α1 =-16.685 and α0 =1173.612. Based on the results of the Nerlove model, the coffee output in the current time period varies significantly with changes in the coffee output in the previous one year. This gives a long run price elasticity of -0.453 implying that a unit change in the price of coffee leads to 0.453 changes in coffee output. If the Nerlove model for UM3 zone is fitted with cost of inputs as the variables, then the results are as presented in Table 8.

TABLE 8: SUPPLY RESPONSE OF COFFEE PRODUCTION WITH NERLOVE MODEL FOR ZONE UM3

Variable	**If Cost of fertilizer is used**		**If Cost of spray is used**	
Coffee output at time t (A_t)	**Coefficient**	**P-value**	**Coefficient**	**P-value**
Cost of Fertilizer used in Kshs (P_{t-1})	-0.037*	0.044		
Cost of Spray used in Kshs (P_{t-1})			-0.025	0.204
Coffee output at time t-1 (A_{t-1})	1.764*	0.000	1.657*	0.000
Coffee output at time t-2 (A_{t-2})	-0.196	0.391	-0.232	0.310
Constant	-66.513	0.788	-155.043	0.522
Chi-Square (3)	136.93*	0.000	133.23	0.000
Within R-Squared	0.1698		0.1721	
Between R-Squared	0.7456		0.7231	
Overall R-Squared	0.3467		0.3405	

Source: Field Data (2016)

The estimation results presented in Table8 shows that the chi-square Wald tests for joint significance for UM3 zone has a value of 136.93 and 133.23 when cost of fertilizer and cost of spray were used, respectively. The associated p-values of 0.0000 for the Wald chi-square statistic shows that the variables included in the model are jointly significant in explaining coffee production in UM3 zone. The estimated value for the overall R-squared is 0.3467 for the model that incorporates the cost of fertilizer. This value shows that the explanatory variables included in the model account for 34.67% of the variation in coffee output in UM3 zone. The estimated value for the overall R-Squared for the model that includes the cost of spray is 0.3405. This value implies that the model explains 34.05% of the variations in coffee output in UM3 zone.

TABLE 9: SUPPLY RESPONSE OF COFFEE PRODUCTION USING NERLOVE MODEL FOR ALL ZONE

Coffee output at time t (A_t)	Coefficient	P-value
Price of Coffee per Kg in kshs (P_{t-1})	2.987	0.313
Coffee output at time t-1 (A_{t-1})	0.838*	0.000
Coffee output at time t-2 (A_{t-2})	0.055	0.288
Constant	51.705	0.670
Chi-Square (3)	759.62*	0.000
Within R-Squared	0.0694	
Between R-Squared	0.8544	
Overall R-Squared	0.4264	
α_1	27.916	
α_0	483.224	
ε	0.800	

Source: Field Data (2016)

From the reduced form equation of the Nerlove model and upon including the cost of fertilizers for zone UM3 without incorporating the cost of spray gives bo = -66,513, b1 = -0.037, b2 = 1.764 and b3 = -0.196. Hence α1 =0.065 and α0 = 117,100. The implication is that based on the Nerlove model, the coffee output in the current time period varies significantly with changes in the coffee output in the previous one year. The estimation results gives a long run price elasticity of 0.514 implying that a unit change in the cost of fertilizer leads to 0.514 changes in coffee output. However, when the cost of spray was included only in the reduced form equation of the Nerlove model in UM3 zone bo = -155.04, b1 = -0.025, b2 = 1.657 and b3 = -0.232. Hence, α1 =0.059 and α0 = 364.807, yielding a long run price elasticity of 0.233. This indicates that a unit change in spray input contributes to a 0.233 change in coffee output. Table 9 gives a summary of the results for supply response of coffee production for all the Zones using the Nerlove model and based on coffee prices as the variable of significance.

The estimation results presented in Table 9 gives a chi-square wald test for joint significance that has a statistic of 759.62 for all zones combined. The associated p-value of 0.0000 for the wald chi-square statistic shows that the variables included the model are jointly significant in explaining coffee production in all zones combined. Furthermore, the estimated overall R-squared value of 0.4264 shows that the explanatory variables included in the model account for 42.64% of the variation in coffee output in all zones combined. From the reduced form equation of the Nerlove model and upon including the price of coffee for all zones gives bo =51.705, b1 =2.987, b2 = 0.838 and b3 =0.055. In this case, α1 =27.916 and α0 =483.224. Hence, based on the Nerlove model, coffee output in the current time period varies significantly with changes in the coffee output in the previous one year. The estimation results give a long run price elasticity of 0.800. The results indicate that a unit change in the price of coffee leads to 0.800 changes in coffee output.

If the cost of inputs is used and the Nerlove model fitted with cost of fertilizers and spray as the variables, then the estimation results is as presented in Table 10. The estimation results presented in Table 10 gives a chi-square wald tests value statistic value of 760.81 when cost of fertilizer is included in the model and a value of 757.99 if cost of spray is included. The associated p-values of 0.0000 for the wald chi-square statistic shows that the variables included the model are jointly significant in explaining coffee production in all zones combined. The overall R-squared has an estimated value of 0.4267 if cost of fertilizer is used and 0.4258 if cost of spray is used. This shows that the explanatory variables included in the model account for 42.67% of the variation in coffee output in all zones combined when cost of fertilizer is used. Similarly, the overall R-squared value of 0.4258 shows that when the cost of spray was used, then 42.58% of the variations in coffee output in all zones combined are explained by the variables in the model.

The results presented in Table 10 shows that if the reduced form equation of the Nerlove model is used and upon including the cost of fertilizers for all zones without incorporating the cost of spray then bo = 123.779, b1 = 0.008, b2 = 0.817 and b3 = 0.051. In this respect, α1 =0.061 and α0 =937.720. Hence, based on the Nerlove model, coffee output in the current time period varies significantly with changes in the coffee output in the previous one year. The results give a long run price elasticity of 0.392. The estimated elasticity shows that a unit change in the cost of fertilizer leads to 0.392 changes in coffee output. However, when the cost of spray is included only in the reduced form equation of the Nerlove model for all zones then bo = 149.528, b1 = 0.002, b2 = 0.834, b3 = 0.055. In this case, α1 =0.018 and α0 = 1347.099. On applying the formula, the long run price elasticity becomes 0.051. This indicates that a unit change in spray input contributes to a 0.051 change in coffee output.

TABLE 10: SUPPLY RESPONSE OF COFFEE PRODUCTION USING NERLOVE MODEL FOR ALL ZONE

Variable	**If Cost of fertilizer is used**		**If Cost of spray is used**	
Coffee output at time t (A_t)	**Coefficient**	**P-value**	**Coefficient**	**P-value**
Cost of Fertilizer used in Kshs (P_{t-1})	0.008	0.192		
Cost of Spray used in Kshs (P_{t-1})			0.002	0.777
Coffee output at time t-1 (A_{t-1})	0.817*	0.000	0.834*	0.000
Coffee output at time t-2 (A_{t-2})	0.051	0.325	0.055	0.290
Constant	123.779**	0.078	149.528*	0.029
Chi-Square (3)	760.81*	0.000	757.99*	0.000
Within R-Squared	0.0690		0.0685	
Between R-Squared	0.8516		0.8527	
Overall R-Squared	0.4267		0.4258	

Source: Field Data (2016)

1) Coffee Production Trend for the Last Ten Years in Kiambu County

.

Coffee production in Kiambu County has been cyclical over the years. Table 11 gives a summary of the mean coffee production for the various zones

TABLE 11: TRENDS IN COFFEE PRODUCTION FOR VARIOUS ZONE

Variable	**Zones**			
	UM1	**UM2**	**UM3**	**All Zones**
	Mean	**Mean**	**Mean**	**Mean**
Coffee output in Kgs	632.271	1641.955	1257.926	1164.002
Coffee price per Kg	36.25	29.87	34.18	33.37
Cost of fertilizer used	4815.522	8624.982	9929.261	7526.521
Cost of spray chemicals used	1489.248	3972.291	4973.773	3295.046
Opportunity cost	5854.545	7236.364	11707.39	7861.382
Labour Cost (30 per cent of TC)	15807.1095	25783.73	34593.551	24287.8337
Total Revenue (TR)	22919.8238	49045.2	42995.911	38842.7467
Total Cost (TC)	27966.4245	45617.37	61203.975	42970.7827
Profits (TR-TC)	-5046.6008	3427.831	-18208.06	-4128.036

Source: Field Data (2016)

The coffee output was on average 632.271 Kgs for UM1 zone, 1,641.955 Kgs for zone UM2, 1,257.926 Kgs for UM3 zone. The mean output for all the zones was 1,164.002 Kgs. In addition, the mean total revenue and total cost was Kshs. 22,919.82 and Kshs. 27,966.42, respectively for Zone UM1; Kshs. 49,045.2 and Kshs. 45,617.37, respectively for zone UM2; and Kshs. 42,995.91 and Kshs. 61,203.98, respectively for zone UM3. The mean total revenue for all the zones was Kshs. 38,842.75 while the mean total cost was Kshs. 42,970.78.

The data presented in Table 11 also shows that on average, coffee farmers in zones UM1 and UM3 made losses while those in zone UM2 made some profits. In this respect, the coffee farmers in zone UM1 made a mean loss of Ksh. 5,046.60 while those in zone UM3 made, which was more than triple that of the farmers in zone UM1. The mean losses for these farmers (zone UM3) stood at Ksh. 18,208.06. In aggregate terms, the coffee farmers in Kiambu county made losses during the period 2004-2014. This may explain the uprooting of coffee trees and shift from coffee farming to other ventures by most of the farmers in Kiambu county.

Table12 gives the trends in coffee production and profitability for the period 2004-2014.

TABLE 12: TRENDS IN COFFEE PRODUCTION FOR VARIOUS YEARS

	2004	2005	2006	2007	2008	2009
Variable	Mean	Mean	Mean	Mean	Mean	Mean
Coffee output in Kgs	1096.744	1240.12	1156.44	1123.272	1075.76	1083.76
Coffee price per Kg	8.38	24.52	24.99	25.06	25.99	27.76
Cost of fertilizer used	9817.28	9430.36	8674.576	8968.16	8456.312	7545.4
Cost of spray chemicals used	3025.896	2831.432	2826.92	2935.56	2802.48	3149.16
Opportunity cost	7312	7387.2	7387.2	7651.2	7651.2	7651.2
Labour Cost (30 percent of TC)	6046.5528	5894.6976	5666.6088	5866.476	5672.9976	5503.728
Total Revenue (TR)	9190.71472	30407.7424	28899.4356	28149.19632	27959.002	30085.178
Total Cost (TC)	26201.7288	25543.6896	24555.3048	25421.396	24582.99	23849.488
Profits (TR-TC)	-17011.01408	4864.0528	4344.1308	2727.80032	3376.0128	6235.6896

	2010	2011	2012	2013	2014
Variable	Mean	Mean	Mean	Mean	Mean
Coffee output in Kgs	1013.928	1121.912	1355.456	1240.544	1296.088
Coffee price per Kg	26.75	73.31	47.6	45.57	37.18
Cost of fertilizer used	6011.04	5054.72	5861.8	6814.48	6157.6
Cost of spray chemicals used	3034.98	3547.34	3540	3757.24	4794.5
Opportunity cost	8088	8088	8088	8588	8583.2
Labour Cost (30 percent of TC)	5140.206	5007.018	5246.94	5747.916	5860.59
Total Revenue (TR)	26075.45	80130.46	58461.49	53995.95	47784.09
Total Cost (TC)	22274.226	21697.078	22736.74	24907.636	25395.89
Profits (TR-TC)	3801.224	58433.382	35724.75	29088.314	22388.2

Source: Field Data (2016)

The data presented in Table12 shows that coffee prices was considerably low in 2004 at Ksh. 8.38 per Kg. However, the coffee prices almost tripled to Ksh. 24.52 per Kg in 2005 and remained at an average of Ksh. 25.66 per Kg up to the year 2010. The coffee prices then shot up considerably in 2011, reaching an all-time high of Ksh. 73.31 per Kg. The high price was, however, not sustained. It declined to Ksh. 47.6 in 2012 and by a further 21.9 per cent to reach Ksh. 37.18 per Kg in 2014. The summaries presented in Table12 also show that coffee farmers in Kiambu county realized a huge loss of Ksh. 17,011.01 from the coffee sales in 2004. The loss suffered by the farmers in 2004 was much higher compared to the marginal profits made by the farmers in 2005-2011. Relatively higher profits were realized in 2012 even this could be largely attributed to increased coffee output.

VI. CONCLUSION AND RECOMMENDATIONS

A. Conclusion

The coffee output increases with the increase in the usage of triple 17 and CAN fertilizers, the usage of spray chemicals, especially copper type of spray, and the increase in the farm acreage. However, the quantity of *sumithion* type of spray used is negatively but statistically insignificant in relation to coffee output. The supply response of coffee output in the current period varies significantly with changes in the coffee output in the previous period and its two-year lag. Educated farmers are likely to be more productive.

B. Recommendation

Based on the findings, this study recommends that farmers should be encouraged to increase the usage of triple 17 and CAN fertilizers. The study is recommending the Government to subsidize the cost of fertilizers and spray chemicals in order to increase the productivity of coffee farms in Kenya. Coffee prices have been a major determinant to increase coffee production globally. To address this challenge, the study is also recommending the use of Linear GARCH model to forecast and predict the international coffee prices which can then be disseminated to the farmers for informed decision making.

The attainment of basic education (primary and secondary education level) is essential for the coffee farmers to enhance their coffee productivity. It *is also recommended that f*armers be trained in agricultural techniques so that they can improve their productivity and livelihoods; better still, farmers can be trained to train other farmers to do better land and crop husbandry.

REFERENCES

[1] African Economic Research consortium, (2007). "The analysis of factors affecting the technical efficiency of Arabica coffee producers in Cameroon"; Paper No. 163, African Economic Research Consortium, Nairobi. Kenya.

[2] Askari, A. and Cummings, T. (1977). Estimating agricultural supply response with the Nerlove model: a survey, *International Economic Review*, 18, 257-329.

[3] Baffes, J., (2003). Tanzania's Coffee Sector: Constraints and Challenges in a Global Environment; The World Bank, Washington, D.C. 20433.

[4] Bagamba, F., Ssennyonga, J.W., Tushemereirwe, W.K., Katungi, E., Gold, C., Katwijukye, A. and Ragama, P. 2003. Analysis of the Banana Production Systems in Uganda: the Case of Ntungamo SubCounty in Ntungamo district. NARO, Kampala.

[5] Bardhan, P., 1973. *Size, Productivity, and Returns to Scale: An Analysis of Farm-Level Data in Indian Agriculture, Journal of Political Economy, vol. 81, issue 6, 1370-86; University of Chicago Press, USA.*

[6] Bichanga, W. O., Mwangi, J. K. (2013). Effects of Liberalization on Coffee Production in Kenya; *European Journal of Business and Management,* Vol.5, No.3. PP 235-256.

[7] Braulke, M., (1982). A note on the Nerlove model of agricultural response, *International Journal of Economic Review***,** *Vol. 23*, 241-244.

CBK, 2014. Kenya Coffee Annual Report, Coffee Board of Kenya, Nairobi Kenya.

[8] Chen, Z., Huffman, W. E., Roselle, S., (2011). Inverse relationship between productivity and farm size: the case of China; Audience: Western Economic Association International, Shanghai, China.

[9] Condliffe, K., Kebuchi, W., Love, C., Ruparell, R., (2008). *Kenya Coffee: A Cluster Analysis;* Boston, USA: Harvard Business School Press.

[10] Consumers International, (2005). *How Coffee is one of the Largest Traded Goods in the world;* London: UK: Consumer International.

[11] Derege, A. E., (2010). *Analysis of Factors Affecting the Technical Efficiency of Coffee Producers in Jimma Zone: a Stochastic Frontier Analysis*. Addis-Ababa: University Addis -Ababa.

[12] FAO, (2013). "Analysis of Incentives and Disincentives for Coffee in Kenya;" Monitoring African Food and Agricultural Policies project, Rome Italy.

[13] Gatete, C. K. (1993). *Economic analysis of Coffee Supply in Kenya*; Vancouver, Canada: University of British Columbia.

[14] Gathura, M. N., (2013). Factors affecting Small-Scale Coffee Production in Githunguri District, Kenya*. International Journal of Academic Research in Business and Social Sciences, Vol. 3, No. 9*. pp134-159.

[15] Government of Kenya, (2014). National Coffee and Average Auction Prices from 2000/01 to 2013/14, Coffee Board of Kenya; Government printers, Nairobi

[16] Government of Kenya, (2010). *Coffee Board of Kenya Annual Reports (2004-2010),* Government printers, Nairobi.

[17] Government of Kenya, (2008). *Kenya Vision 2030*; Government printers, Nairobi.

[18] Hausman, J. (1978). Specification Tests in Econometrics. Econometrics, 46, 1251-1271. https://doi.org/10.2307/1913827

[19] International Coffee Council, (2015). *Sustainability of the coffee sector in Africa;* International Coffee Council 115th Session 28 September – 2 October 2015 Milan, Italy http://www.ico.org/documents/cy2014-15/icc-114-5-r1e-overview-coffee-sector-africa.pdf;http://www.cargill.com/learning-journey/africa/five-challenges-facing-africa/index.jsp Retrieved on 5th Feb, 2016.

[20] International Coffee Organization, (2014). The International Coffee Organization 1963-2013: 50 years serving the world coffee community. London UK.

[21] International Coffee Organization, (2004). Monthly Coffee Market Report, London UK.

[22] Jimma Research Center, (2011). *Arabica Coffee research and Development Intervention can improve Coffee Production and productivity*; Addis-Abab: Ethiopian institute of Agricultural Research.

[23] Journal of Third studies, (2006). *The Status of global Coffee Economy in Africa, Asia and Latin America*; Cambridge, United Kingdom

[24] Kalyebera, R., (1999). *A report on comparison of factors affecting adoption of improved coffee management recommendations between small and large scale farmers*; Kampala: Makerere University.

[25] Karanja, A. M. (2002). *Liberalization and smallholder agricultural development in Central Kenya*; Denmark: Wageningen University.

[26] Karanja, A. M., (2002). "Liberalization and smallholder agricultural development: A case study of coffee farms in Central Kenya". PhD Thesis, Wageningen University; Netherlands.

[27] Kegode, P., (2005). "Economic Governance of Coffee Sector in Central Province of Kenya"; Center for Governance and Development; Nairobi

[28] Kibaara, B., Ariga, J., Olwande, J., Jayne, T. S., (2008). "Trends in Kenyan Agricultural Productivity": 1997-2007; Tegemeo Institute of Agricultural Policy and Development, Nairobi, Kenya.

[29] Machuka, S. M., (1989). "Evaluation of strategies to increase Coffee output by the Year 2000 and beyond: a Kenyan Case study"; M.A. Thesis, University of Guelph, Ontario, Canada.

[30] Maitha, J., (1969). "Coffee Production in Kenya: An Econometric Study"; PhD Thesis, University of, Nairobi, Kenya.

[31] Masterson, T., (2007). Productivity, Technical Efficiency, and Farm Size in Paraguayan Agriculture; Working Paper No. 490; The Levy Economics Institute of Bard College, Annandale-on-Hudson, USA.

[32] Mofya-Mukuka, R., 2011. *Effects of policy reforms on price transmission and price volatility in coffee markets: Evidence from Zambia and Tanzania.* D.Sc. Thesis, Christian-Albrecht University-Kiel, Germany.

[33] Mofya-Mukuka, R. and A. Abdulai, 2012. *Supply Response of Export Crops in Zambia: The Case of Coffee*; Indaba Agricultural Policy Research Institute; Lusaka, Zambia. http://www.aec.msu.edu/fs2/zambia/index.htm

[34] Mugweru, E. K., (2011). *Determinants of Coffee production in the Kenyan economy* http://erepository.uonbi.ac.ke:8080/handle/123456789/3203. Retrieved on 3rd March, 2013.

[35] Mureithi, L. P., (2008). "Coffee in Kenya: Some Challenges for Decent Work"; Geneva, Switzerland, International Labour Office (ILO).

[36] Nakabo, S. (1992). "An Econometric Supply Response Modei, for Coffee in Uganda"; University of Manitoba, Winnipeg, Manitoba. Canada.

[37] Nassiuma D. K. (2000). Survey sampling: Theory and methods. Njoro, Kenya: Egerton University Press.

[38] Nchare, A., (2007). "Analysis of factors affecting the technical efficiency of coffee producers in Cameroon". Department of Monitoring and Evaluation, Ministry of Agriculture and Rural Development Yaoundé, Cameroon.

[39] Njaramba, S. G., 2011. Supply response of Kenyan Coffee in The World Market; MSc. Thesis, Kenyatta University, Nairobi Kenya.

[40] Odhiambo, W., Nyangito, H. O., Nzuma, J. (2004). "Sources and Determinants of Agricultural Growth and Productivity in Kenya"; Discussion paper No. 34, KIPPRA, Nairobi, Kenya.

[41] OKoboi, G. (2011). "Improved inputs use, productivity and commercialization in Uganda maize production"; Kampala, Uganda.

[42] Omwoyo, S. (2008). Assessment of the effect of Coffee production on Abagusii women in Western Kenya; *East African Journal of Humanities and Sciences Vol. 2, No 1*. pp 180 – 190.

[43] Theuri, B. N., (2012). "Factors Affecting Coffee Revitalization Programs in Mukurweini district Nyeri County, Kenya". University of Nairobi. http://erepository.uonbi.ac.ke:8080/xmlui/handle/123456789/7180. Retrieved on 15th November 2014.

[44] The Kenya Coffee Network, (2014). "Coffee Growing Regions in Kenya": file:///C:/Users/CMM/Desktop/Coffee%20Growing%20Regions%20In%20Kenya%20%20%20Kenya%20Coffee%20Network.htm. Retrieved on 15th November 2014.