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Determinants of Productivity of Small-scale Holdings of Arabica Coffee in Kenya: A Case Study of Kiambu County, Kenya

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Abstract:
This study explores the effects of farm size, the use of fertilizers and chemical sprays on the productivity of coffee farms in Kiambu County in Kenya. The study uses both fixed and random effects techniques to estimate the magnitude of the contribution of each factor to coffee productivity. The study findings show that there is a positive and statistically significant relationship between coffee output and quantity of fertilizer used in zone UM2. However, a negative and statistically significant relationship is found for zone UM3. Moreover, this study finds a positive and statistically significant relationship between the quantity of spray used in litres and coffee output for zone UM1. The estimation results also indicate that both the farm size and the quantity of triple 17 and CAN fertilizers used are positively and statistically significant related with coffee output; this relationship, however, does not hold for the case for sumithion type of fertilizer. Based on the findings, this study recommends that farmers should increase the quantity usage of compound fertilizer in the form of triple 17, and those who do not use fertilizers have to be encouraged to use triple 17 fertilizer. It is also recommended that the government ought to subsidize the cost of fertilizers and spray chemicals in order to increase the productivity of coffee farms in Kenya.

Keywords: *Productivity of Small-Scale Holdings, Arabica Coffee, Kenya*

1. Introduction

More than twenty years since liberalization began, coffee production in Kenya has declined and remains depressed for almost two decades. More particularly, between 1987/88 to 2012/13 coffee production in Kenya declined by more than 60% mainly in the small holdings. The declining productivity of coffee is partly due to lower use of inputs, marketing problems, poor governance of cooperatives and international market conditions (Theuri, 2012). As a results, 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 tonnes in 2008/09 to 36,300 tonnes in 2010/11 and increased slightly to 39,800 tonnes 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.

Although the coffee sub-sector plays a key role in Kenya's economy by significantly contributing towards foreign exchange earnings, family incomes, employment creation and food security; it is generally acknowledged that coffee production and more so coffee productivity has not been impressive during the past two decades in the Kenyan economy, it is shocking to note that there is no an empirical study that has attempted to estimate and examine the magnitude of this problem in Kiambu, County. Kiambu is the highest producer of coffee and with many small scale farmers.On the average, 56% of coffee is produced by smallholders (co-operatives) on individual plots of less than 2 hectares (or 5 acres).

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 calls for the development d delivery of both dis-embodied and embodied technical changes that can increase the productivity of one or more inputs. On the other hand, low productivity forms a basis for policies geared towards increasing productivity through more efficient use of resources within the current technology.

This study therefore, seeks 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). It is important to note that recent studies that have attempted to explore the relationship between farm size and efficiency (i.e., productivity) have used a two step methodology where efficiency measures are computed and are regressed on farm specific characteristics (Fletschner and Zepeda, 2002; Nyemeck *et al.*, 2003; Dhungana, Nuthall and Nartea, 2004; Helfand Levine, 2004).Nonetheless, the results from various literature have been ambiguous and most of the earlier studies were not concerned with overall productivity of small holder farming. In addition, most of these studies have mainly used time series or cross sectional data separately. In this study panel data approach was used to explore coffee productivity in Kenya. 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.

The estimated results show that there is a positive and statistically significant relationship between coffee output and quantity of fertilizer used in zone UM2. Moreover, this study finds a positive and statistically significant relationship between the quantity of spray used in litres and coffee output for zone. The estimation results also indicate that both the farm size and the quantity of triple 17 and CAN fertilizers used are positively and statistically significant related with coffee output; this relationship, however, does not hold for the case for *sumithion* type of fertilizer. Based on the findings, this study recommends that farmers should increase the quantity usage of compound fertilizer in the form of triple 17.

The remainder of this study is organized as follows. Section 2 reviews the literature on the relationship between farm size and its productivity. While section 3 sketches out the methodology, section 4 presents and discusses the empirical results. Section 5 concludes.

2. Literature Review

The nexus between farm size and coffee productivity is one of the oldest topics in agriculture and development economics in general. Interest in the inverse relationship between farm size and productivity arose in the 1970 sout of the observation that for Indian farms, yields are inversely related to farm size (Bardhan,1973;RaoandChotigeat,1981;Deolalikar,1981). 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. It soon became the most cited empirical observation in third world countries.

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. Several studies tried to bring in new issues not yet analyzed but which are believed to be important determinants of the observed inverse relationship (Bardhan, 1973; BhaUa, 1988; Bhalla and Roy, 1988; Barret, 1994). Ellis (1993) and Barret (1994) review major explanations given for the observed inverse relationship. An overview of these literature show that the observed negative relation could be due to market failures (imperfections), a consequence of decreasing returns to scale, a consequence of a superior efficiency of smallholders with respect to the intensity of utilization of land as a resource, and other region specific factors like soil fertility or quality.

In Kenyan context, Mwabu *et al* (1998) found out that the productivity effect of agricultural extension is highest at the extreme ends of the distribution of yield residuals. This finding suggests that for a given level of extension input, unobserved factors such as farm management abilities affect crop yields differently. Effects of schooling on farm yields are positive but statistically insignificant. 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

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.

3. Methodology

3.1. 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:

$$n = \frac{Nc^2}{c^2+(N-1)e^2} \qquad 1$$

Where $\boldsymbol{n}$ is the total sample size from the three coffee zones in Kiambu County, $\boldsymbol{N}$ is the total smallholders coffee farmers in Kiambu County (which is about 32% of smallholdings in Kenya), $\boldsymbol{c}$ = coefficient of variation (≤ 30%) and $\boldsymbol{e}$ = 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.

3.2. Econometric Modelling

Consider a small hoder farmer who produces coffee using a technology described by the production function:

$$Y(X_1, X_2, X_3) = AX_1^{b1}X_2^{b2}X_3^{b3} \quad (1)$$

Where Y is the Coffee output, A denotes total factor productivity. X_1 stands for the coffee farm sizes in hectares, X_2 stands for the quantity of fertilizers used in a year; and X_3 denotes quantity of spray chemicals used in a year. The values given as b_1, b_2, b_3 are output elasticities obtained by translogging the function into a generalized Cobb-Douglas production function form. Hence, by taking the logs of the above equation, it becomes:

$$\ln Y_t = \ln A_t + b_1 \ln X_{1_t} + b_2 \ln X_{2_t} + b_3 \ln X_{3_t} + \mu_t, \quad t = 1,2,3...,n \quad (2)$$

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:

$$y_t = a_t + b_1x_{1t} + b_2x_{2t} + b_3x_{3t} + \mu_t \quad (3)$$

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

$$y_{it} = a_{it} + b_1x_{1it} + b_2x_{2it} + b_3x_{3it} \quad (4)$$

If we write $a_{it} \equiv \alpha_i + \mu_{it}$, then we can re-write equation (4) as follows:

$$y_{it} = \alpha_i + b_1x_{1it} + b_2x_{2it} + b_3x_{3it} + \mu_{it} \quad (5)$$

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

$$E(\mu_{it} | x_{1i}, x_{2i}, x_{3i}, \alpha_1, ..., \alpha_n) = 0 \quad (6)$$

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

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

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

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

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

$$E(y_{it} | X, \alpha) = x_{it}^{'}b + d_{it}^{'}\alpha \quad (8)$$

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:

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

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.

4. Results and Discussion

4.1. 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 6 gives the summary of the unit root test based on the Breitung Test.

	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*

Table 1: Breitung Panel Unit Root Tests
** denotes statistical significance at the 5 percent level*

Table 1shows 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.

4.2. 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 estimators, 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.

4.2.1. Results of Fixed Effects

As can be seen in table 2 below results for fixed effects model show that holding all factors constant, an increasein 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.

4.2.2. Results of Random Effects

As can be seen in table 2 below 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 below.

	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

Table 2: Hausman Test

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.

4.3. 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* (2004) 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

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		

Table 3: Coffee Productivity Using Pooled OLS Regression Model with Dummy Variables

4.4. 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 gives 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 parameter estimate 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.

	UM1 zone		**UM2 zone**		**UM3 zone**		**All Zones**	
Ln Coffee output	Coef	P-value	Coef	P-value	Coef	P-value	Coef	P-value
Ln Farm size Acres	-0.072	0.580	0.566*	0.000	0.369**	0.060	0.349*	0.000
Ln Fertilizer Quantity KG	0.013	0.871	0.435*	0.000	0.258*	0.011	0.277*	0.000
Ln Spray Quantity litres	-0.094	0.383	0.028	0.639	0.070	0.493	0.021	0.668
Constant	6.114*	0.000	4.407*	0.000	5.298*	0.000	5.083*	0.000
Returns to scale	-0.153		1.029		0.697		0.647	

Chi-Square (3)	1.10	0.7770	78.13*	0.0000	15.54*	0.0014	63.83*	0.0000
Within R-Squared	0.3852		0.4917		0.4931		0.5427	
Between R-Squared	0.3561		0.3930		0.4561		0.5159	
Overall R-Squared	0.4729		0.5821		0.4616		0.5252	

Table 4: Coffee Productivity Using Cobb-Douglas Production Function

Upon computing the sum of b_1, b_2 and b_3 we get -0.072, 1.029, 0.697, and 0.647 for zone UM1, zone UM2, zone UM3 and for all zones combined, respectively. The findings show that in UM1 zone coffee production technology in Kiambu County exhibits decreasing returns to scale since the computed value is less than 1. However, the coffee production technology used in zone UM2 exhibits increasing returns to scale. The results presented in Table 4 also shows that coffee output is positively and significantly related to acreage planted, hence increases in acreage leads to an increase in coffee output for all zones save for zone UM1.

Similar findings emanated from a study by Mugweru (2011). In addition, Bussolo*et al* (2007) also deduced the same findings in Uganda, that more coffee production was as a result of increased farm acreage under coffee, meaning that the more land one allocates to coffee the more coffee output expected. The study further reveal that the quantity of fertilizer used in kilograms is positively and statistically significant in relation to coffee output, though statistical significance was not deduced for zone UM1. However, the results indicate that there is a negative, but statistically insignificant relationship between coffee output and quantity of spray used in litres in zone UM1. Similarly, a positive and statistically insignificant relationship was deduced for UM2 zone, UM3 zone and all zones combined. This implies that a reduction in spray quantity have no influence on coffee output.

4.5. 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.

	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

Table 5: Individual Contribution of Inputs to Coffee Productivity

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.

The individual contribution of coffee productivity by inputs for various years is presented in Appendix 2. The findings show that farm size in acres was positively and significantly related to coffee output only the year 2013, implying that an increase of farm size by one acre lead to an increase in the yield of coffee productivity by 1.781Kgs in the year 2013. 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 the years 2004 to 2014.

5. Conclusion and Recommendations

The regression results of the pooled OLS regression Model presented in table 3 showed that coffee output is positively related to the acreage planted. The coefficient of the farm size variable was statistically significant at 1 per cent significance level. Similarly, according to the model results, coffee productivity increases with fertilizer used but not the quantity of spray. The results also show a positive relationship between coffee output and quantity of fertilizer used in kilograms in all zones, but more statistically significant in UM2, which is a main coffee growing zone. However, 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 estimation results indicated that the quantity of triple 17 fertilizers used in kilograms is positively and statistically significant in relation to coffee output. In addition, the quantity of CAN fertilizer used is positively and statistically significant in relation to coffee output. Further, the quantity of copper type of spray used was positively and statistically significant in increasing the coffee output. However, the quantity of sumithion type of spray used is negatively but statistically insignificant in relation to coffee output. The estimation results also showed 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.

Based on the findings, this study recommends that farmers should increase the quantity usage of compound fertilizer in the form of triple 17, and those who do not use fertilizers have to be encouraged to use triple 17 fertilizer. It is also recommended that the government ought to subsidize the cost of fertilizers and spray chemicals in order to increase the productivity of coffee farms in Kenya. And lastly, there has been considerable volatility (and uncertainty) in the past few years in the international coffee prices. Most farmers and financial analysts are concerned about the uncertainty of the returns on their production, caused by the variability in speculative coffee prices and the instability of coffee performance. Volatility has become a very important concept in different areas in financial theory and practice, such as risk management, portfolio selection, derivative pricing. Coffee prices have been a major determinant to increase coffee production globally. To address this challenge the Linear GARCH model can be used to forecast international coffee prices which can be disseminated to the farmers for informed decision making.

6. References

i. Askari, A. and T. Cummings, 1976, Agricultural supply response: A Survey of the Econometric Evidence (New York, Praeger).
ii. 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
iii. Bichanga, W. O., Mwangi, J. K., (2013). Effects of Liberalization on Coffee Production in Kenya.Jomo Kenyatta University of Agriculture and Technology, Nairobi.
iv. Bichanga, W. O., Mwangi, J. K., (2013). Effects of Liberalization on Coffee Production in Kenya; European Journal of Business and Management, ISSN 2222-1905 (Paper) ISSN 2222; Vol.5, No.3.
v. Bloomberg Business week, (2013): http://www.businessweek.com/news/2013-02-26/brazil-seen-reaping-record-coffee-harvest-for-an-off-year
vi. Brazil Coffee annual report (2005). Coffee production, distribution and how it's traded through exportation (Agricultural Trade Office), Sao Paulo
vii. Bussolo, M., Godart, O., Lay, J., Thiele, R. (2007). The impact of coffee price changes on rural households in Uganda, Journal of Agricultural Economics (2007) pp273-303,
viii. Bussolo, M., Godart, O., Lay, J., Thiele, R. (2007). The impact of coffee price changes on rural households in Uganda, Journal of Agricultural Economics (2007) pp243-248,
ix. Centre for Agricultural Research and Ecological Studies (CARES) (2010). The application of microbial organic fertilizer for safe coffee production; Hanoi Agricultural University, Vietnam Sao Paulo State University; African Journal of Agricultural Research.
x. Chen, Z., Huffman, W. E., Roselle, S., (2011).Inverse relationship between productivity and farm size: the case of China; Audience: Western Economic Association International ISSN: 1074-3529, China
xi. Condliffe, K., Kebuchi, W., Love, C., Ruparell, R., (2008). Kenya Coffee: A Cluster Analysis; Harvard Business School, USA.
xii. Consumers International, (2005).How Coffee is one of the largest traded goods in the world; Consumer International, London
xiii. Department of Economics, (2009).Fair trade Coffee and Development; University of Lund Sweden
xiv. Department of Economics, (2009).Coffee gains from its marketing in Ethiopia; Lund University, United Kingdom
xv. 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**.**
xvi. Evenson, R. E., Mwabu, G., (1998). The effects of agricultural extensionon farm yields in Kenya. Center Discussion Paper No. 798, Economic Growth Center Yale University, New Haven, Connecticut 06520-8269
xvii. FAO, (2013). Analysis of Incentives and Disincentives for Coffee in Kenya; Monitoring African Food and Agricultural Policies project (MAFAP), FAO, Rome.

xviii. Federal Ministry for Economic Cooperation and Development, (2007).How climate changes affect coffee production; Federal Ministry for Economic Cooperation and Development, Frankfurt, Germany

xix. 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 .ISSN: 2222-6990

xx. Government of Kenya, (2011).Annual Kenya Economic Surveys (2003-2011); Government printers, Nairobi

xxi. Government of Kenya, (2010).Coffee Board of Kenya Annual Reports (2004-2010), Government printers, Nairobi

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

xxiii. Government of Kenya, (2010).Annual Farm Handbooks (2006-2010); Ministry of Agriculture, Nairobi

xxiv. Government of Kenya, (2010).Annual Statistical Abstracts (2006-2010); Kenya National bureau of Statistics, Nairobi

xxv. Government of Kenya, (2010).Annual Kenya Statistical Abstracts (2004-2010);Kenya National bureau of Statistics, Nairobi

xxvi. Government of Kenya (2010).Annual Kenya Agricultural Farm Management Hand books (2006-2010), Government printers, Nairobi

xxvii. Government of Kenya, (2008).Kenya Vision 2030; Government printers, Nairobi

xxviii. Government of Kenya, (2008).Kenya First Medium Term Plan (2008); Government Printers, Nairobi

xxix. Henning Oien, (2010). The Farm Size-Productivity Relationship in the South African Land Reform: Subdividing for Success; Master thesis for the Master of Economic Theory and Econometrics degree, Department of Economics, University of Oslo, Norway

xxx. International Trade Centre, (2011). The Coffee Exporter's Guide Third Edition, ITC, Geneva

xxxi. International Trade Centre, (2010). Climate change and the coffee industry; Technical Paper, International Trade Centre (ITC); Geneva.

xxxii. International Coffee Organization, (2014). The International Coffee Organization 1963-2013: 50 years serving the world coffee community.

xxxiii. International Coffee Organization, (2004).Monthly Coffee Market Report

xxxiv. Jimma Research Center, (2011).Arabica Coffee research and Development Intervention can improve Coffee Production and productivity; Ethiopian institute of Agricultural Research, Addis-Ababa

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

xxxvi. Kalyebera, R., (1999). A report on comparison of factors affecting adoption of improved coffee management recommendations between small and large scale farmers; Makerere university, Kampala

xxxvii. Karanja, A.M., (2002). Liberalization and smallholder agricultural development in Central Kenya; Wageningen University, Denmark

xxxviii. Karanja, A. M., (2002). Liberalization and smallholder agricultural development: A case study of coffee farms in Central Kenya. PhD Thesis, Wageningen University; Netherlands. ISBN 90-5808-603-8

xxxix. Kegode, P., (2005). Economic governance of coffee sector in central province of Kenya; Center for Governance and Development; Nairobi

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

xli. Lemes, L.N., L.B. Carvalho, M.C Souza and P.L.C.A Alves, (2010). Investigation of the effect of weed on coffee fruit production; Sao Paulo State University

xlii. Luong, Q. V.andTauer, L. W. (2006).A real options analysis of coffee planting in Vietnam, Journal of Agricultural Economicspp49-57

xliii. 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

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

xlv. 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, NY 12504-5000, USA

xlvi. Mauritson, B.M. and Nielsen, A.A., (2011). Coffee Production and Development in Latin America; Coffee Research Institute, Tapales, Nicaragua

xlvii. Mugweru, E. K., (2011). Determinants of Coffee production in the Kenyan economy