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

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A THESIS SUBMITTED IN FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY OF THE OPEN UNIVERSITY OF TANZANIA

2016

CERTIFICATION

We, the undersigned do certify that we have read and hereby recommend for acceptance by the Open University of Tanzania a thesis entitled: “D**eterminants of Productivity of Small-Scale Holdings of Arabica Coffee and its Supply Response in Kenya: A Case Study of Kiambu County”** in fulfillment of the requirements for the Degree of Doctor of Philosophy.

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Date

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DECLARATION

I, **Samson Masese Machuka**, do hereby declare that this thesis is my own original work and that it has not been presented to any other University for a similar or any other degree award.

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Signature

……………………………………

Date

DEDICATION

This work is dedicated to my wife Leah and my children, Kevin, Brian, Allan and Ian.

ACKNOWLEDGMENT

I am grateful to Dr. Khatibu Kazungu and Prof. Charles M.M. Ondieki for their guidance, supervision and valuable advice during this course of the research project. I also wish to convey my sincere thanks to the Kiambu County small scale coffee farmers and managers of the various coffee factories and societies for providing both primary and secondary data that was used in the study. I also wish to thank the Coffee Board of Kenya, the Kenya National Bureau of Statistics, the Ministry of Agriculture and Livestock Development and the Kenya Planters Cooperative Union for providing secondary data and additional information that enriched the study.

Many thanks also go to my colleagues and friends for valuable information that helped me in some of the discussion of project results. I would also like to thank my family for the encouragement they gave me throughout the course. Heartfelt thanks goes to my wife, Leah and son Allan for their patience and understanding throughout the research and writing of the thesis.

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. 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 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.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

CBK	Coffee Board of Kenya
KNBS	Kenya National Bureau of Statistics
KPCU	Kenya Planters Cooperative Union
LM	Lower Mid land Zone
M.A	Master of Arts
MoA	Ministry of Agriculture
SAS	Statistical Analysis System
SPSS	Statistical Program for Social Scientists
UM1	Upper Mid land Zone 1
UM2	Upper Mid land Zone 2
UM3	Upper Mid land Zone 3

DEFINITION OF TERMS

Several terms used in this research are defined below as follows:

(i) **Agricultural productivity** -is a measure of the ratio of agricultural outputs to agricultural inputs. While individual products are usually measured by weight, their varying densities make measuring overall agricultural output difficult. Therefore, output is usually measured as the market value of final output, which excludes intermediate products such as corn feed used in the meat industry. This output value may be compared to many different types of inputs such as labour and land (yield). These are called partial measures of productivity. Agricultural productivity may also be measured by what is termed total factor productivity (TFP). This method of calculating agricultural productivity compares an index of agricultural inputs to an index of outputs. Changes in TFP are usually attributed to technological improvements.

(ii) **Small Holdings** – Refers to farmers with coffee farms up to 5 acres.

(iii) **Large scale farming** – Refers to farmers with coffee farms more than 5 acres

(iv) **Arabica Coffee-** This is the oldest and traditional coffee variety that is grown in all upper midland zones in Kenya. It is high quality coffee that is in high demand all over the world.

(v) **Ruiru11 Coffee-** This is a coffee variety that was grafted in Kenya in mid 1980s and is a dwarf (900mm) in length but can double yields where it is grown. It is suitable in the same zones like Arabica and takes shorter time to start yielding (3 years compared to Arabica which takes 5years). However its management and nutrient requirement is more intense compared to Arabica.

(vi) **Robusta Coffee-** This type of coffee only grows in lower midland zones characterized by warm climates and fairly dry areas. The variety as already mentioned is good for producing instant coffee

(vii) **Upper midland zone 1 (UMI) -** This is a tea-coffee zone area identified by agricultural professionals.

(viii) **Upper-midland zone 2 (UM2**) **-** This is a main coffee growing zone

(ix) **Upper-midland 3 (UM3)** - This is a marginal coffee growing zone; it is suitable for growing subsistence crops such as maize, potatoes, vegetables among others.

(x) **Lower-midland zone (LM)** - This is a zone characterized by warm climate and dry in nature and suitable for growing Robusta coffee variety.

(xi) **Coffee Outpu**t- Output at farm level for this study

(xii) **Coffee productivity**- Coffee output per inputs

(xiii) **Coffee profitability** – Coffee income less costs

(xiv) **Technical efficiency** - is the effectiveness with which a given set of inputs is used to produce an output. A firm is said to be technically efficient if a firm is producing the maximum output from the minimum quantity of inputs, such as labor, capital and technology. Productive efficiency is concerned with producing goods and services with the optimal combination of inputs to produce maximum output for the minimum cost.

(xv) **Productive efficiency-** To be productively efficient means the economy must be producing on its production possibility frontier.

(xvi) A**llocative efficiency -**This occurs when there is an optimal distribution of goods and services, taking into account consumer's preferences

CHAPTER ONE

INTRODUCTION

1.1 Background Information

The Coffee Industry in Kenya is noted for its cooperative system of milling, marketing, auctioning, and for its high percentage of production from small farms. Kenya is the fifteenth largest producer of coffee in the world, (International Coffee Organization Report, 2014), producing well over 51 million kilograms and exported about 50 million kilograms in 2015. 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.

Kenya has more than 700,000 smallholder farmers, 2,000 small estates and 200 large estates engaged in the production of coffee (ECOM, 2013). The smallholder farms account for an estimated seventy percent of the country’s total coffee production. Coffee production takes place mainly in upper and midland zones which are mainly suitable for growing Arabica coffee. The coffee contributes the highest income for smallholders in the coffee growing areas. These incomes, therefore, have a significant effect on the national economy in general and more especially in the rural areas. Hence, Coffee plays a major role in the development of Kenya and its performance has far-reaching socioeconomic consequences.

According to Government of Kenya (2014), the area under coffee decreased from 121,300 hectares in 2008/09 to 115,600 hectares in 2010/11 and to 109,800 hectares in 2012/13. During this period coffee production decreased from 54,000 tonnes in

2008/09 to 36,300 tonnes in 2010/11 and to 39,800 tonnes in 2013. Coffee productivity decreased from 605.6 Kg/Ha in 2011/12 to 492.3 Kg/Ha in 2012/13. The decline was attributed to rising costs of farm and processing inputs as shown in table 4.27 where the total cost of Kshs. 42,971/= exceeded the total revenue of Kshs. 38,843/= for the period 2004 to 2014 for all the coffee zones per farmer.

The price of coffee increased from 220 US cents/kg in 2013 to 388 US cents/kg in March 2014 (Government of Kenya, 2014). However, the 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 productions. 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.

Bichanga and Mwangi (2013) carried out a study and found out that both the short and long-run Kenyan total exports are price inelastic with a coefficient at -0.95. However, their findings showed that vegetable product exports including tea, coffee and horticulture are price elastic estimated at 4.0, which contribute significantly to Kenya’s exports. These findings suggest the need to improve on the production and export of tea, coffee and horticulture.

1.2 Kenya's Administrative Boundaries and the Location of the Study Area

Kiambu County, which is in Central Kenya, is one of the 47 counties in Kenya. It is also one of the counties with high agricultural potential in the country. The county borders Nairobi City in the South, Nakuru County and Nyandarua County to the

West, Nyeri County to the North and Muranga and Machakos Counties to the East. Kiambu County is the main Arabica coffee producer in the country. The area under coffee in the county is approximated at 13,704 ha (The Kenya Coffee Network, 2014). Of these, 20.5% or 2,814 ha is on plantation farms while the balance of 79.5% or 10,890 ha is on smallholder farms (The Kenya Coffee Network, 2014).

The smallholder farms comprise 22 active co-operative societies with a total active membership of over 50,150 coffee growers. The estimated annual production is 15,633 mt for Estates and in excess of 2,560mt for smallholders (The Kenya Coffee Network, 2014).

Kiambu County has a bi-modal rainfall pattern and two cropping seasons. The long rain season is from March to August and the short rain season is from October to mid-February. Cash crops in the region are coffee, tea and horticultural crops such as vegetables and cut flowers. Maize, beans and bananas are the dominant staple food crops while dairy and small ruminants are the dominant livestock activities (Sasa News, 2012). Coffee growing is spread over three ecological zones in the Upper Midland zone (UM1, UM2 and UM3). These zones are classified according to climatic conditions of temperature, rainfall, soil types and crop suitability.

Table 1.1 shows quantity of coffee produced from each county in Kenya. As illustrated in Table 1.1, Kiambu County is the highest producer of coffee in the country. This provides the rationale for choice of Kiambu County for this study.

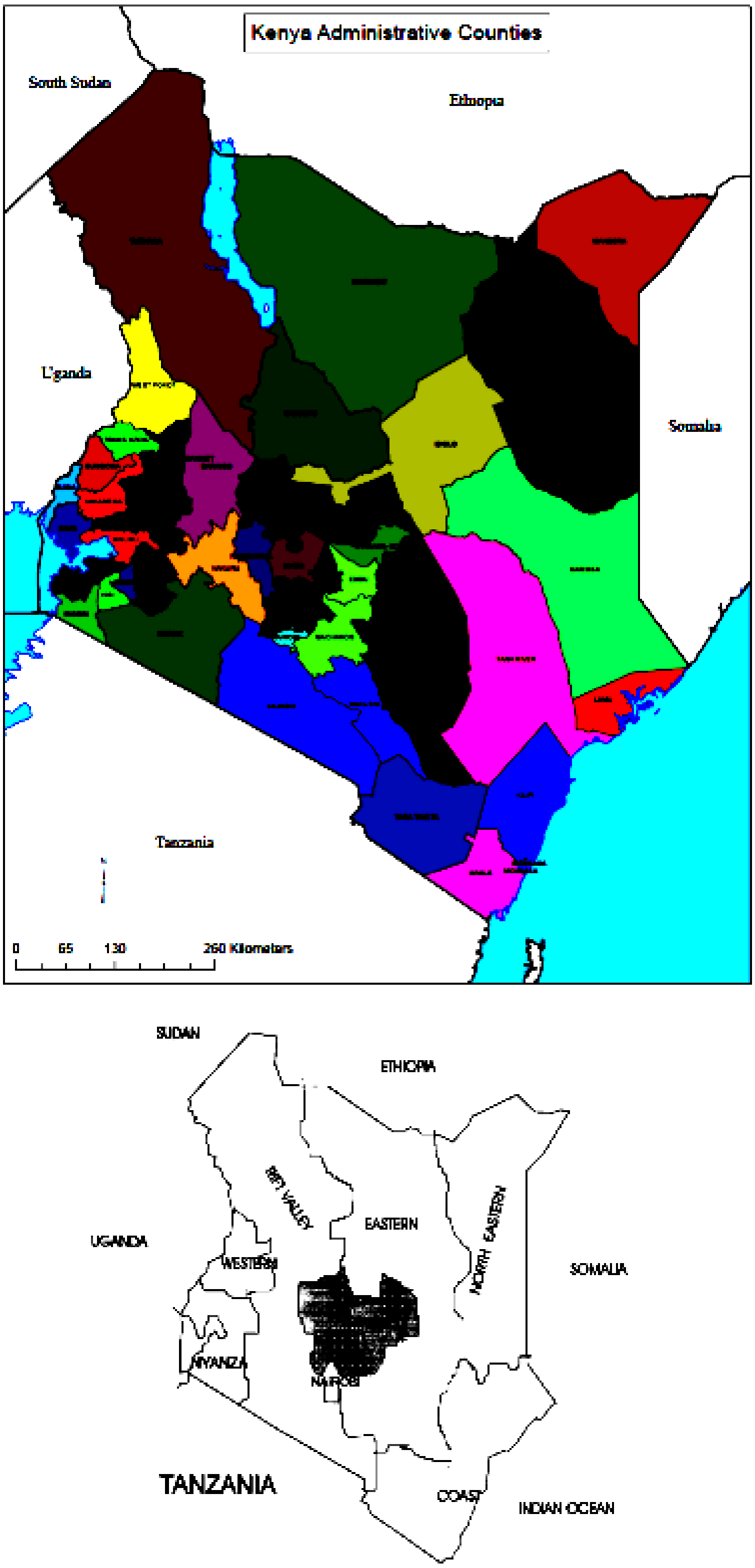

Figure 1.1: Map of Kenya showing Counties

Source: Independent Election and Boundaries Commission (IEBC)

Kiambu County: Kiambu County is a county in the Central Province of Kenya. It has a total population of 1,623,282 people. The County has 496,244 households and covers an area of 2,543.4 SQ. KM. The Population density is 638 per square kilometre.

Some strengths of Kiambu County include:

1. Natural resources as Arable land, Forests, Water Falls
2. Tourist attractions as Mau Mau Caves, Paradise Lost, Chania Falls and Fourteen Falls, Mugumo Gardens, Christina Wangare Gardens
3. Main Economic Activities include Farming, Food Processing, Manufacturing (Leather), Mining (Carbacid), Textile (Cotton), Motor Vehicle Assembly, Wholesale and Retail Trade

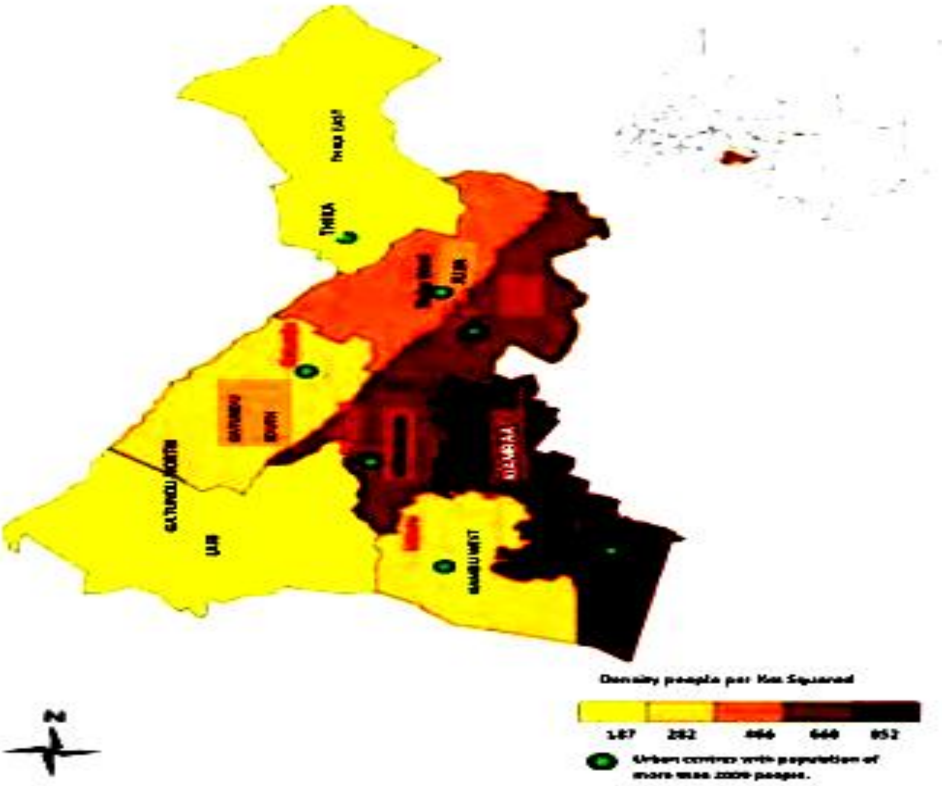

Figure 1.2: Kiambu County Map

Source: Independent Election and Boundaries Commission (IEBC)

Table 1.1: Clean Coffee Production by County 2012/13

No.	**County**	**Total Production (KGS)**	**Per cent**
1.	Kiambu	12,736,361	31.96
2.	Kirinyaga	5,181,485	13.00
3.	Nyeri	4,483,773	11.25
4.	Embu	2,318,773	5.82
5.	Muranga	2,245,695	5.64
6.	Kisii&Nyamira	2,162,252	5.43
7.	Meru	2,074,318	5.21
8.	Machakos	1,952,978	4.90
9.	Bungoma	1,758776	4.41
10.	Kericho&Bomet	1,692,430	4.25
11.	Makueni	1,025,544	2.57
12.	Tharaka-Nithi	907,020	2.40
13.	Nakuru	488,877	1.23
14.	Trans Zoia	256,559	0.64
15.	Nandi	238,267	0.60
16.	Homa Bay &Migori	71,768	0.18
17.	UasinGishu	46,381	0.12
18.	Baringo	19,071	0.05
19.	Elgeyo&Marakwet	16,335	0.04
20.	West Pokot	11,055	0.03
21.	Laikipia	8,297	0.02
22.	Kakamega&Vihiga	7,663	0.02
23.	Narok	1,463	0.00
24.	The rest of the Country	83,262	0.21
	Total	**39,848,392**	**100.00**

Source: Coffee Board of Kenya (2015)

1.2.1 The Global Coffee Performance

As explained earlier, the International Coffee Organization composite daily price of coffee increased from under 220 US cents/kg in November 2013 to a high of 388 US cents/kg in March 2014. This increase was driven by a serious drought in Brazil, with several coffee growing regions centre around Minas Gerais receiving little or no rain during the critical development months of January and February 2014 (International Coffee Organization, 2014). This trend is encouraging for coffee farmers in Kenya; however, most farmers have already abandoned coffee farming and switched to other alternative land use such as livestock keeping, fish bonds or even growing other crops.

Coffee, which is grown in more than 50 countries, is produced primarily for consumption as a beverage by more than one third of the world's population. It provides a source of revenue for many people. Brazil, which is the biggest exporter of coffee, produced 56.8 million bags of coffee in 2012/13 season, and accounted for more than 30% of world coffee exports (Bloomberg Business week, 2013).

Globally commercial coffee production is based on two species, Coffee Arabica and Coffee acanephora, which are often referred to as Arabica coffee and Robusta coffee, respectively. More than 60% of global coffee production is based on Arabica, which is considered to produce beans of higher quality and therefore demands a higher market value. On the other hand Robusta, which is often grown at lower altitudes, is better suited to warmer and more humid tropical environments than Arabica and, can withstand more adverse conditions; it is also more resistant to coffee pests and diseases.

According to the International Coffee Organization (2004), the coffee production in the year 2002/2003 was more than 120 million bags while the demand was less than 110 million bags. This explained why the international coffee prices were low. The low consumption was due to low coffee quality in the global market. This led to economically unsustainable coffee farming especially in the small holdings. This impoverished the small coffee producers in Kenya.

However, according to the International Trade Centre (2011), the coffee production in the year 2010/2011 was more than 131.1million bags while the demand was 130.9 million bags. This means that demand was almost equal to the supply. But according to World-Coffee-Slithering-Prices (2013),between 2011/2012 and 2013/2014, global coffee consumption was expected to rise from 141.6 million bags during 2011/2012 to 141.9 million bags during 2013–2014, thus showing that consumption was increasing and therefore prices of coffee were improving steadily. The coffee production in Kenya was expected to increase to take advantage of the good global coffee prices that were prevailing then; unfortunately this was not the case thus indicating the existence of a problem with the coffee production.

1.2.2 Coffee Production in Africa

Africa is the region with the largest number of coffee producing countries: 25 as opposed to 11 in Asia and Oceania, 12 in Mexico and Central America and 8 in South America. Production in Africa has exhibited negative growth over the last 49 years. Average production was 19.4 million bags per crop year in the period between 1965/66 and 1988/89 when the coffee market was regulated under the export quota system. During the period between 1989/90 and 2014/15 under the free market, average production per crop year was 16 million bags. During those two periods, Africa's share of world production has hence decreased from 24.9% to an average of 14%. Production in crop year 2014/15 was around 16.9 million bags, or 12% of the estimated world production of 141.7 million bags. Of this, an estimated 10.4 million bags were produced by just two countries (Ethiopia and Uganda).

In the period between 1989/90 and 2014/15, only 4 African countries ranked among the top 20 coffee producing countries that account on average for 93.7% of world production. The four African countries in question, which accounted for only 9.9% of world production, are Ethiopia (3.9%), Uganda (2.6%), Côte d'Ivoire (2.5%) and Kenya (0.9%).

A steady decline in production has been observed in Kenya as average production since 2000/01 has fallen below 800,000 bags compared to 1.5 million bags from 1970/71 to 1999/2000. In crop year 2014/15 Kenya's total production is estimated at 850,000 bags. Until the 1980s coffee was the leading foreign exchange earner before being overtaken by tea, horticulture and tourism. Tanzania is the fifth largest African coffee producing country with an average annual production of around 800,000 bags; there has been substantial improvement since crop year 2012/13, and production for 2014/15 was estimated at above 1 million bags after slipping back to 809,000 bags in 2013/14.

The most dynamic growth in African production was observed in Ethiopia, which has recorded an average annual growth rate of 2.2% over the past 50 years, increasing to 2.7% since crop year 1989/90. The country's production trend is generally upward despite some downward interruptions, reaching around 6.6 million bags in 2014/15. To a lesser extent, Uganda has recorded sustained growth in its production, with an annual average fluctuating between 2.7 and 3 million bags since the 1970s. Its production level is estimated at 3.8 million bags in 2014/15.

1.2.3 Performance of the Coffee Industry in Kenya

For a very long time coffee remained the most important agricultural export in Kenya and in 2011 it accounted for more than 40% of the total value of exports (Gathura, 2013). However, in the period of 2005-2009, coffee accounted for only about 6% of agricultural exports, while horticulture and tea exports increased substantially to 34% and 32% of agricultural exports, respectively (FAO, 2013). Coffee contribution dropped further to 3% when production fell from a peak of 128.7 million kilograms in 1987/1988 crop year to a record low volume of 51 million kilograms year 2013.

The coffee sector has continued to play a key role in Kenya's economy due to its substantive contribution to foreign exchange earnings, family incomes, employment creation, food security and a major plank in delivering the 10% annual growth rate under the economic pillar of Vision 2030. 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).

Between 1987/88 to 2012/13 coffee production in Kenya declined by more than 60% mainly in the small holdings. This low productivity in smallholder farms therefore remains one of the major challenges to be overcome if coffee is to remain a viable farm enterprise. However, coffee production remains one of the major cash crops in many parts of Kenya. The main coffee producing regions in Kenya are on deep, fertile and acidic volcanic soils found in the highlands between 1400 to 2000 meters above sea level. These regions produce high quality, milder Arabica coffees that are known for their intense flavor, full body and pleasant aroma. The climate in these regions is mild, with an average temperature of less than 19°C and an annual precipitation of at least 1000 mm.

In central Kenya (where Kiambu County is situated), annual rainfall is distributed in a bimodal pattern that results in two distinct flowerings each year, shortly after the beginning of the long rains in March/April and October. Rainfall in western Kenya is more evenly distributed, resulting in somewhat different Arabica coffees that compete with Jamaica blues. The main crop ripens from October to December, with the short rains crop harvest beginning in May.

Kenya has a dual production system with about 3 300 large-scale coffee estates and over 700,000 smallholder producers organized into about 550 cooperatives. Smallholders account for75% of the land planted under coffee but only accounts for slightly over half of production. Yields are much higher on the estates because of the more intensive use of fertilizers, pesticides, herbicides and fungicides, as well as irrigation. Smallholder farmers use fewer purchased inputs and practices such as mulching for water conservation and weed control.

The price decline only partly explains the problem because production in other countries has increased since 1992. Global coffee production resumed its long-term growth rate trend of about 1.35% per year after 1992. The International Coffee

Agreement (ICA) system, which operated from 1962-1989, resulted in restrictions in production that favored African Arabica; its dissolution resulted in a period of adjustment and a reduced African share of global coffee production, while Brazil and Vietnam increased their share in world markets based on a cost advantage for their value chains. In the case of Kenya, some of the growth before 1989 appears to be due to ICA restrictions on other producers rather than inherent competitiveness. However, this does not explain the long period of stagnation after 1992.

Another possible reason may have to do with productivity. Kenyan producers pay a cess of 1% on coffee sales to fund coffee research. In contrast, most other agricultural commodities are funded by the government and by the international community because research for these commodities is seen as a public good. This method does not provide enough finance for coffee research and, therefore, may have something to do with the decline in coffee exports.

Most coffee in Kenya is susceptible to Coffee Leaf Rust and Coffee Berry Disease, which necessitates the use of fungicides. A resistant variety, Ruiru 11 has not proved popular because it appears to produce an inferior quality coffee. Although important, the development of new, resistant varieties of coffee so as to increase production has also proved difficult.

Finally, there is the issue of the operation of the cooperatives themselves. The cooperatives are authorized to process and market smallholder coffee through the Nairobi Coffee Auction. Smallholder growers may have a choice in which cooperatives they belong to, but private coffee buyers are proscribed. There are 8 marketing agents who represent growers at the auctions and about 50 dealers who buy coffee at the auctions and sell it to overseas customers. However, the largest part of the value chain after the farm gate is the responsibility of the cooperatives. The efficiency of the cooperatives is critical to the competitiveness of Kenyan coffee production, and there is some reason to believe that considerable improvements could be made.

Kenya grows mainly Arabica coffee variety. The predominant commercial varieties are the SL28, SL34, K7 and Ruiru 11. Pockets of the Blue Mountain and French mission still exist in the older establishments. Coffee Board of Kenya (CBK) estimates the total area under coffee to be about 170,000 Ha. There are two harvesting seasons in a year, in Oct-Dec (main crop) and the May-July (early crop). In 2008/2009 CBK estimated that there were over 700,000 smallholders who marketed their coffee through about 550 Co-operative Societies. The CBK also estimated that there were 3,300 small to medium estates with farm size ranging from 5 to 10 hectares and 100 large estates with sizes of between 10hectares and over 200 acres. This situation has not changed much. Each cooperative owns and manages one or more wet-processing factories.

Records from various Economic Surveys 2001 to 2014, as shown in Table 1.2, indicate that on average, 44% of the production is under the estate subsector and 56% is produced by smallholders (co-operatives) on individual plots of less than 2 hectares (or 5 acres). This shows a shift from about 15 years ago when smallholders were producing about 66% of the total production. It is noted in the table that the area under coffee for both smallholdings and estates remained constant at 170,000

Hectares between 2001/02 to 2005/06 but declined to 163,000 Hectares and 155,000 Hectares in 2006/07 and 2007/08 respectively.

The Coffee Hectarage increased modestly to 160,000 Hectares and remained the same for the rest of the period between 2008/09 to 2013/14. It is also noted that productivity varied even when the coffee hectarage remained the same realizing a high of 326.1 Kg/Ha in the period 2000/01 and 2004/05. The Highest productivity achieved in the entire period was at 337.5 Kg/Ha in 2008/09 even when Hectarage had declined to 160,000 Hectares. Tables 1.2 clearly illustrates this information for the period 2000/01 to 2013/14.

Table 1.2: Coffee Production 2000/01 – 2013/14

Production years	Estates Production (MT)	Smallholders/Coops Production (MT)	National Production (MT)	Ha under Coffee	Productivity (Kg/Ha)
2000/01	19,280	31,263	50,543	170,000	297.3
2001/02	19,795	32,100	51,895	170,000	305.2
2002/03	21,148	34,295	55,443	170,000	326.1
2003/04	18,473	29,958	48,431	170,000	284.9
2004/05	20,745	24,500	45,431	170,000	267.2
2005/06	21,975	26,860	48,835	170,000	287.3
2006/07	23,850	29,150	53,000	163,000	325.2
2007/08	18,900	23,100	42,000	155,000	271.0
2008/09	24,600	29,400	54,000	160,000	337.5.
2009/10	19,700	22,300	42,000	160,000	262.5
2010/11	16,700	19,600	36,300	160,000	225.0
2011/12	22,000	27,000	49,000	160,000	306.3
2012/13	17,900	21,900	39,800	160,000	248.8
2013/14	22,940	27,060	50,000*	160,000	312.5

Source: Various Economic Surveys, 2001-2014

Table 1.3 shows coffee production, area under coffee in hectares and productivity in the period between 2000/01 to 2013/14 under the smallholdings. As illustrated in Table 1.2, the area under coffee remained constant at 128000 hectares between 2000/01 and 2005/06. The Hectarge however declined to 121,000 Hectares and 118,000 Hectares in 2006/07 and 2007/08 respectively. The coffee Hectarage remained the same at 120,000 hectares between 2008/09 to 2013/14. It is noted that productivity in the smallholdings remained low compared to the overall levels of the two sectors. For instance in the year 2000/01 productivity was 244.2 Kg/Ha compared to 297.3 Kg/Ha for the two sectors as shown in Table 1.2. The same tre3nd is seen in all the years up to 2013/14. This means that coffee productivity in the smallholdings is extremely low in comparison with the overall national average. Table 1.3 gives a summary of coffee production by smallholders over the period 2000/2001 to 2013/2014.

Table 1.3: Coffee Production by Smallholders 2000/01 – 2013/14

Production years	Smallholders/Coops Production (MT)	Ha under Coffee	Productivity (Kg/Ha)
2000/01	31,263	128,000	244.2
2001/02	32,100	128,000	250.8
2002/03	34,295	128,000	267.9
2003/04	29,958	128,000	234.0
2004/05	24,500	128,000	191.4
2005/06	26,860	128,000	209.8
2006/07	29,150	121,000	240.9
2007/08	22,300	118,000	189.0
2008/09	29,400	120,000	245.0.
2009/10	22,300	120,000	185.8
2010/11	19,600	120,000	163.3
2011/12	27,000	120,000	225.0
2012/13	21,900	120,000	182.5
2013/14	27,060	120,000	225.5

Source: Various Economic Surveys, 2001-2014

Table 1.4 shows coffee production, area under coffee in Hectares and productivity in the period between 2000/01 to 2013/14 under the Estates. The area under coffee remained constant at 42,000 hectares between 2000/01 and 2006/07. The hectarge, however, declined to 37,000 Hectares in 2007/08 and remained at 40,000 Hectares between 2008/09 to 2013/14. It is noted that productivity in the Estates remained high compared to the overall levels of the two sectors. For instance in the year 2000/01 productivity was at 459.0 Kg/Ha compared to 244.2 Kg/Ha of the small holdings and 297.3 Kg/Ha of the National average as can be seen in both Tables 1.2 and 1.3. The same trend is seen in all the years' up to 2013/14. This means that coffee productivity in the Estates is above the National average and generally twice as high of the smallholdings. This difference in productivity between Smallholdings and Estates could be attributed to a number of factors that would include; extension services, farming skills and knowledge, proper use of inputs and use of mechanization in farming.

Table 1.4: Coffee Production by Estates 2000/01 – 2013/14

Year	Estates Production (MT)	Ha under Coffee	Productivity (Kg/Ha)
2000/01	19,280	42,000	459.0
2001/02	19,795	42,000	471.3
2002/03	21,148	42,000	503.5
2003/04	18,473	42,000	439.8
2004/05	20,745	42,000	493.9
2005/06	21,975	42,000	567.9
2006/07	23,850	42,000	616.3
2007/08	19,700	37,000	532.4
2008/09	24,600	40,000	615.0
2009/10	19,700	40,000	492.5
2010/11	16,700	40,000	417.5
2011/12	22,000	40,000	550.0
2012/13	17,900	40,000	447.5
2013/14	22,940	40,000	573.5

Source: Various Economic Surveys, 2001-2014

The summaries presented in Table 1.4 show that coffee production in the estates increased modestly from 19,280 MT in 2000/01 to 21,148 MT in 2002/03. The coffee output, however, declined 2,675 MT to reach 18,473 MT in 2003/04. Thereafter, the production appeared cyclical and stood at 22,940 MT in 2013/14. Overall, the area under coffee production reduced from 42,000 ha in 2000/01 to 40,000 ha in 2013/14. This may be as a result of the low returns from coffee prompting farmers to clear the coffee bushes and turn the coffee firms into other ventures such as housing estates. As illustrated in Table 1.4, coffee productivity has also been cyclical over the years. It recorded a low of 417.5 kg/ha in 2010/2011 and a high of 616.3 kg/ha in 2006/07.

1.2.4 Challenges Faced by Small-scale Farmers Globally

Small-scale farmers need access to good-quality inputs, good-quality soil, a functioning and productive climate, and access to land to enable them produce food and other cash crops. The price of inputs is often determined by the international price of energy because farm inputs like fertilizers are very energy intensive; therefore, many small-scale farmers simply can't afford expensive modern agricultural inputs. This is one of those factors that are beyond the ability of the farmer to control. Similarly, the weather is something that farmers can't control and as we move forward in the 21st-century, and into a world of more severe climate change, the weather is likely to become less predictable.

Finally, access to land is another area that is completely outside of the control of the small-scale farmer. They need to have secure land tenure, which is very unlikely for some of the world's poorest and most marginal. What's more, as food prices rise, international businesses increasingly are buying up productive land across the developing world displacing small-scale farmers in the process.

Another problem smallholder farmers face when trying to increase productivity is where to get the capital to buy modern agricultural inputs; in most developing countries it is very difficult for farmers to obtain the capital to buy even fertilizer let alone herbicides, pesticides and improved seeds. Farmers, therefore, sometimes go into debt at exorbitant rates of interest to loan to buy inputs and if crops fail they have no way of paying back their loans. As a result, promoting modern agricultural inputs, in the absence of financial institutions, may result in worse income and greater volatility.

Similarly, smallholder farmers struggle with access to markets. They generally lack storage and processing facilities. And they struggle to distribute and market their produce(https://feedingninebillion.com/sites/feedingninebillion.com/files/publications/Understanding%20Small%20Scale%20Farming%20in%20the%20Developing%20World%20Poster.pdf)

1.2.5 Challenges Faced by Small-scale Coffee Farmers in Eastern Africa

Many smallholder farmers in Africa depend on the production and selling of coffee. Growing coffee as a cash crop on small pieces of land in Africa is not easy. The growing conditions for coffee farmers in East Africa have become more unpredictable in the last ten years. Erratic and often adverse changes to weather patterns make coffee growing more a lottery than an art. Rains are starting late, delaying crop planting and resulting in late coffee flowering and berry ripening. That means delays for farmers in earning income from their coffee. Rains are also falling more heavily in intense cloud bursts, causing localized flooding, flattening crops, and knocking coffee cherries off coffee bushes.

Farmers in the mountains of Eastern Hararghe in Ethiopia say they are experiencing rising temperatures and drought, while Kenyan farmers around Mount Kenya are experiencing unseasonably cool temperatures and less sunshine, contributing to falling coffee yields and increasing disease and pests. Farmers believe that their coffee bushes are becoming ‘confused’, which is not a good thing when your family’s livelihood depends heavily on the money you making from your coffee crop.

Population pressures lie at the heart of the land management challenges facing farmers in Ethiopia and in Kenya. There are too many people trying to make a living on too small areas of land. Agricultural productivity, economic development, human development and standards of education and health have improved very little – certainly not enough to keep pace with the growth in population. The land is almost at point, in Ethiopia at least, where any dramatic change in weather and climate could have a catastrophic impact on the people.

In Kenya, the coffee smallholder farmers face similar challenges to those in Ethiopia. Population pressures and the size of smallholdings are comparable, but there are also some important differences. The Nyeri Highlands around Mount Kenya are greener and lusher, with more tree cover and less severe erosion and soil loss. Certain agricultural challenges are common to both countries. All farmers need to maintain soil fertility for coffee production, and for other crops. Pests and diseases are a growing problem for all agricultural activities and coffee has its fair share. Shifting weather and climate are bringing new coffee boring insects such as thrips, new fungal infections such as coffee leaf rust infection, and new diseases. And less predictable weather conditions also make it more difficult to spray against these blights. Kenyan coffee farmers in particular spend a large amount of time, money and effort spraying against coffee berry disease (CBD) and pests. It is highly likely that there is widespread misapplication of the wide array of (often inferior) chemicals that have been marketed to coffee farmers. Misapplication of chemical inputs is worse than no application.

Farmers in Kenya do not actually get paid for their coffee crop until after the crop has been sold at auction, which may be six months after they have first delivered their beans to a primary cooperative. This, therefore, means that farmers are heavily reliant on credit, charged at high rates of interest, and on the provision of education, health and input credits from their cooperative or local credit unions. And these farmers are part of Fair Trade certified supply chains.

Coffee production in Tanzania is a significant aspect of its economy as it is Tanzania's largest export crop and contributes about $115 to the country’s export earnings. Tanzanian coffee production averages between 30-40,000 metric tons each year of which approximately 70% is Arabica and 30% is Robusta. About 95 percent of coffee is produced by some 400,000 smallholders on average Plots of 1-2 hectares and 5 percent is grown on estates (Baffes, 2003). Most of the smallholders do not use purchased inputs such as chemicals and fertilizer; only a quarter of smallholders use purchased inputs. The farmers are faced with many constraints; among the key constraints are an overly complicated tax code with tax rates that are too high and in some cases regressive, excessive involvement of the state, which discourages and weakens the private sector and a mandatory nature of the coffee auction. The Tanzanian Coffee Board is responsible for disseminating price and other information and for monitoring the quality of auction coffee sales and other coffee statistics to farmers.

1.2.6 Five Big Challenges Facing Africa's Agricultural Productivity

Each day – all around the world – farmers face the same common threats to their productivity and livelihood. In Africa, however, the challenges go beyond damaging weather, pests and disease. And, with 80 percent of Africa's farmers cultivating less than two hectares (five acres), getting to know small-scale farmers is essential to understanding the hurdles facing the continent's agricultural productivity. There are five main challenges that face Africa's agricultural productivity:

(a) Critical inputs

Farmers at all scales of production need access to the inputs required to produce a successful crop – high-yielding seeds, effective fertilizer and sufficient water. Even when these are available, input pricing is often too high for smallholders – resulting in fertilizer use in Sub-Saharan Africa of just one-tenth the world average.

(b) Access to financing

Challenging legal and financial environments are constraining growth in African agriculture. For smallholders, especially, credit is often inaccessible or unaffordable.

Without appropriate financing, farmers are not only less able to invest in their operations but also much more vulnerable to market volatility and unpredictable weather.

(c) Property rights

According to the Food and Agriculture Organization (FAO) of the UN, secure land tenure and property rights can drive poverty reduction, rural development and global food security in developing countries. Farmers with clear land ownership are motivated to reinvest in their operations and increase production beyond subsistence farming, selling the surplus. Yet in many parts of Africa, farmers are unable to own their land and pledge it as collateral, limiting their incentive to reinvest in their businesses.

(d) Infrastructure for market access

Farmers generally can earn higher prices outside of harvest season – yet few African smallholders have access to proper storage to take advantage of price fluctuations. Furthermore, many smallholders live in isolated, rural areas. Infrastructure like paved roads, reliable energy, warehouses and cold storage not only benefits farmer livelihoods but improve food security by reducing post-harvest loss.

According to FAO, 40 per cent of the population in Sub-Saharan Africa lives in landlocked countries, versus just 7.5 per cent in other developing countries. That means farmers in this region require greater access to primary cross-border markets – access that is made slow and costly by poor roads, long delays at borders and other issues.

(e) Off-farm income

It may sound counter-intuitive, but off-farm income is critically important to agricultural development. The first migrants from farms to cities often send money back to their family members. Those remittances can fund better farm inputs – seed, fertilizer and machinery, for example. The resulting improvement in productivity enables more people to leave the countryside for cities where their incomes, and their diets, tend to improve – boosting demand and prices for farm output. In short, farmers and farm output benefit when urban workers have incomes sufficient to purchase food at prices that encourage farmers to produce more.

(f) Low adoption of new technologies

African production has been seriously undermined by the continued reliance on out-dated and often unproductive coffee varieties in the face of the widespread prevalence of pests and diseases, including coffee leaf rust, coffee berry borer, coffee stem borer, and coffee wilt disease among others (International Coffee Council, 2015).

Although many initiatives have been taken in some countries, many challenges remain to achieve a sustainable coffee sector in Africa. The main challenge is how to move the African coffee sector from a subsistence sector to an entrepreneurial one. Farmers need sustainable income generation and long term security of livelihood. Productivity is still too low to be able to promote sustainable coffee production in the case of long periods of low prices. In many African countries, the smallholder sector consists of a large number of widely scattered small farming operations, often with limited physical accessibility and very poor communications. Moreover, given the weak research and extension support, farmers in many countries have been slow to adopt good practices that could lead to the required high quality and productivity. Changes in climate that affect production areas add to the challenges (International Coffee Council, 2015).

1.3 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. Due to time and financial constraints this study investigated and determined the effect of farm size, type of fertilizer used and the type of chemical spray used on coffee productivity; this formed the main objective of this study. The study conducted a detailed case study on the effect of the three factors of production of coffee productivity in Kiambu County.

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

Table 1.5: 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.

1.4 Research Objectives

1.4.1 General Objective

The main objective of this study is to investigate the determinants of productivity of coffee farms and its supply response in the Kiambu County in Kenya.

1.4.2 Specific Objectives

(i) To 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) To find out the individual contribution to coffee productivity by farm size, type of fertilizer used and the type of chemical spray used in Kiambu County.

(iii) To estimate and analyze short run and long run supply response of coffee production by using Nerlove model.

(iv) To explore the coffee production trend for the period 2004 to 2014 in Kiambu County.

1.5 Research Questions

The following research questions guided this study;

(i) Is the contribution to coffee productivity of farm size, type of fertilizer used and the type of chemical spray used when combined form the main contribution to coffee productivity in Kiambu County?

(ii) Is the contribution to coffee productivity of each of the factors of production i.e. farms size, type of fertilizer used and the type of chemical spray used equal in Kiambu County?

(iii) Is the coffee supply response in Kenya influenced by the international coffee prices?

(iv) What is the short term and long term supply response of coffee production by using the Nerlove model?

(v) Has the coffee production remained constant for the last ten years in Kiambu County?

1.6 Justification of the Study

The quality of coffee is highly influenced by the quality and quantity of factors of production used, and the farming practices. It is on this basis that the researcher recognized the need to investigate and determine the effects of the factors that contribute to the productivity of coffee in Kenya today. Presently both the quality and quantity of coffee produced by Kenyan farmers especially smallholdings are low and therefore very low income is gotten from coffee farming. This has made many farmers uproot the crop and replace it with alternative other subsistence crops. This trend therefore called for a major research to come up with measures that would salvage the otherwise deteriorating important coffee sector that would make significant contribution to Kenya’s envisaged vision 2030.

Most previous studies of coffee supply response have used regression-based models. Coffee production is typically decomposed into two parts: potential production (investment) as a long-term component, and the proportion of potential production harvested as a short-term component (Wickens and Greenfield, 1973). The investment component is usually seen as comprising the planting decision, modelled as a function of coffee prices lagged the length of the gestation period, and the removal decision, determined by one-year lagged and current prices (Arak, 1969).

The yield decision is explained, in most studies, through three variables: current price, price lagged one year, and output lagged one year. The current and one-year lagged prices represent the expected immediate returns. The inclusion of one-year lagged output accounts for the biennial production cycle of Arabica, especially in Brazil. Some models 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).

The study investigated and determined the contribution of farm size, type of fertilizer used and the type of chemical spray used to coffee productivity in Kiambu County. The three are the main factors that affect agricultural production according to the

Agricultural Sector Development Strategy for Kenya, 2010-2020. The findings will assist the Government and individual farmers in decision making as to which factor and quantity to give more priority so as to increase coffee productivity. This is likely to assist in providing greater insight into the production and financing the factors that contribute towards coffee production. Kiambu County was selected as the area of study since it is one of the counties with most small scale coffee producers in Kenya; the region was also easily accessible to the researcher.

The research would also fill the gaps in the studies previously carried out by other researchers regarding the declining of coffee production in Kenya and also enable other researchers to carry out the study beyond this scope. The study will also give a better understanding of the issues under investigation and also sharpen the researcher's skills.

1.7 Scope of the Study

The study investigated the determinants of productivity of coffee farms and its supply response in Kiambu County. Kiambu County was chosen because it is one of the main coffee producing counties in Kenya. The study used panel data for the period 2004 to 2014 collected from farmers in coffee producing zones UM1, UM2 and UM3 in the county.

1.8 Organization of the Study

This study is organized into five chapters. Chapter one provides the introduction to the study. It discusses the background to the study by highlighting Kenya's administrative boundaries and the location of the study area. It also discusses the performance of coffee production at global and national levels; statement of the problem; and research objectives and research questions. The chapter also provides a justification for undertaking the study, and the scope of the study. Chapter two provides the literature review in terms of theoretical and empirical literature while Chapter three contains methodology. In this respect, Chapter three identifies and discusses the research design and methods, and data collection and analysis. Chapter four is on results and discussion. It reports and discusses the findings based on the study objectives. The last Chapter (five) contains summary, conclusions and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This section looks at both the theoretical and Empirical literature that relate to coffee farm productivity and the supply response of the selected research area of Kiambu County in Kenya.

2.2 Farm Productivity

2.2.1 Theoretical Framework

Productivity is defined as the ability of a unit of an input to produce a certain level of output (Harsh et al., 1981, p.130). Thus, it shows how efficient a farmer is in the use of that particular input given the range of alternative technologies available to him. The productivity measure is given by the average physical product of the input which itself is defined as the total physical product divided by the total amount of the input used in production (Ellis, 1993). For example, labor productivity is the average output per unit of labor used.

Productivity is usually multiplied by the output price in order to facilitate comparisons across products, farms or regions, to aggregate over products or simply to compare them to factor prices. For example, the marginal physical product multiplied by the price of the product derived from the additional unit of the input is the marginal value product of the input.

Farm productivity can be calculated for one or more crops. For one crop, physical product will be preferred to value product while for multiple crops, aggregation is required using product prices and thus the preference for the value product. Likewise, in the denominator one input can be used, and that will be referred to as the "partial factor productivity," or all inputs can be used giving rise to the notion of "total factor productivity" if all products are used in numerator.

If the farmer is economically rational and there is no constraint in the use of inputs, the farmer should operate at the economic optimum, the level of use of inputs where the marginal value product of each input equals its unit cost. This means that the additional return of the input must equal the additional cost of the input. Stated differently, the optimum condition corresponds to the point where the ratio of the marginal value product of the input to the price of that input is equal to one. Then, if the ratio is higher than one, the farmer is applying too little of the input and if the ratio is less than one he is using too much (Ellis, 1993).

These cases arise when farmers are constrained in their access to complementary inputs as seen above. For example, a farmer constrained in his access to land or capital (credits for example) will use more labor than required thus driving the ratio of the marginal value product of labor to the wage of labor below one. Or, if for example the marginal value product of seed is above its price that means that farmers could efficiently use more seed. However, the quantity of additional output obtained for each successive additional unit of seed (marginal physical product) will get smaller as the amount of seed increases (law of diminishing returns) until, eventually, the ratio of the marginal value product of seed to its unit cost (price) will equal one. But for some reasons (such as credit limits), farmers are constrained in their access to seed.

The theory of utility maximization has been used extensively (Johnston and Masters, 2004; Khanna, 2001) to explain the preference of inputs by farmers. It is presumed that farmers prefer to use an input if and only if the utility derived from the input is higher than the use of other inputs. Although we cannot observe the underlying internal decision-making process of the farmer, we can observe whether the farmer has preferred the use of a specific input or not, hence, the preference is modeled as a binary choice variable. There is extensive use of univariate logit and probit models in studies involving farmers' preferences. These models assume that farmers make decisions on the preference of each input independently of the others although this differs much from reality as farmers are faced with multiple preferences in the realm of production, management and marketing

When farm decision making involves consideration of multiple preferences, farmers will employ various criteria to choose one or more inputs from the set. One important criterion is whether preference of a specific input is preconditioned by an earlier use of the specific input such that the synergistic effect of the two increases the system's productivity. If the former use of the input increases the marginal benefits of using it alone or together with others, then we have a symbiotic or complementary relationship between the use of one or more additional input. The ultimate challenge is that it will result into a multicollinearity scenario, which however has a mechanism of solving it.

Such relationship is best modeled as sequential and requires the use of conditional probabilistic models as in Khanna (2001) and, Johnson and Masters (2004). The use of the Tobit model as in Johnson and Masters (2004) is adopted so as to measure both the probability of preference and the partial elasticities of different socioeconomic factors on preference that will lead to productivity and profitability conditional on exceeding the pre-set cut point.

The productivity of a production unit can also be measured by the ratio of its output to its input (Lovell, 1993). However productivity varies according to differences in production technology, production process and differences in the environment in which production occurs. The main interest here is in isolating the efficiency component in order to measure its contribution to productivity.

Producers are efficient if they have produced as much as possible with the inputs they have actually employed and if they have produced that output at minimum cost (Greene, 1997). The overall performance involves the measurement of efficiency, effectiveness, and the degree to which a system achieves programs and policy objectives in terms of outcomes, accessibility, quality and appropriateness (Worthington and Dollery, 2000).

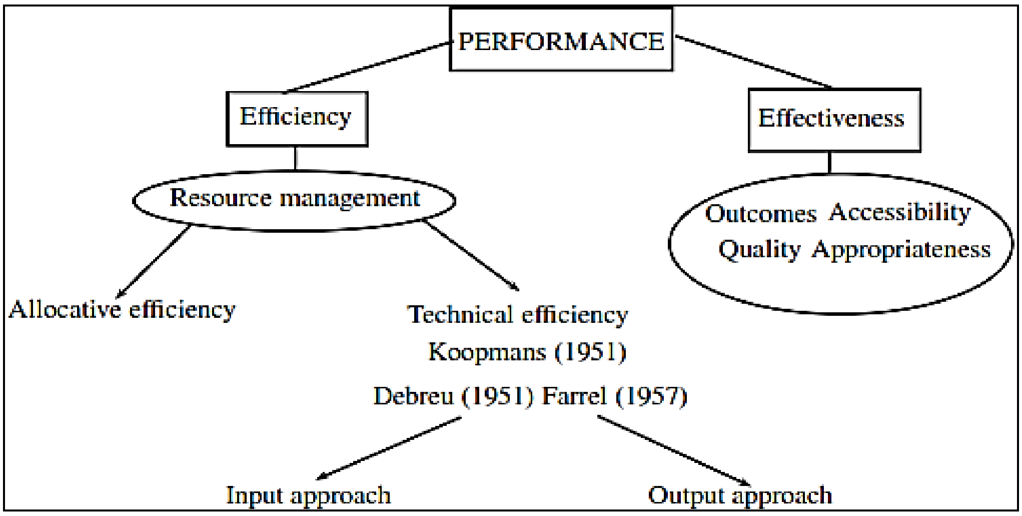

Figure 2.1: Conceptual Framework

Source: Author

Both technical and allocative efficiency can be measured by two main approaches:
The input approach if one is considering the ability to avoid waste by producing as much output as input usage allows, i.e. we evaluate the ability to minimize inputs keeping outputs fixed;
The output approach if one is considering the ability to avoid waste by using as little input as output production allows, i.e. we evaluate the ability to maximize outputs keeping inputs fixed.

In this research the Input Approach is most appropriate to use; this approach can be used by farmers to find the ideal combination of inputs to maximize coffee production i.e., to be fully efficient. However this approach is not sufficient to obtain technical efficiency as it is possible to increase production by reducing one input without increasing the other input.

On the other hand, following the pioneering work of Farrel (1957), economic efficiency (or Performance) is disaggregated into two components: Technical Efficiency (TE) and Price or Allocative Efficiency (AE). Technical Efficiency refers to the ability of a firm to obtain the maximum possible output from a given set of resources and technology. Technical Efficiency is therefore the ability of the farmers in this study to avoid waste by producing as much output as input usage allows or by using fewer inputs as output production requires.

Allocative Efficiency generally refers to a firm's ability to maximize profits by equating the marginal revenue product with marginal cost or input. This allocative efficiency refers to the farmer's ability to combine inputs in optimal proportions given the prevailing set of prices (Fred, Lovell and Schmidt, 1983). In Farrel's frameworks, economic efficiency is therefore an overall performance measure and is equal to the product of both technical efficiency and allocative efficiency. Therefore, economic efficiency is a broader efficiency than the traditional efficiency concept which mainly dwells on allocative efficiency. This modern efficiency concept is viewed more in terms of a system performance which includes farmers and farm support systems rather than focusing on farmers rationality.

Analysis and measurement of farmers economic efficiency are therefore important as the level of efficiency has 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 and delivery of both dis-embodied and embodied technical changes that can increase the productivity of one or more inputs. On the other hand, low economic efficiency forms a basis for policies geared towards increasing productivity through more efficient use of resources within the current technology. This means that investments will be needed in the area of input delivery systems, extension services, information technology and better pricing and marketing strategies.

Recent studies exploring the relationship of farm size and efficiency have used a two-step methodology. In the first step, efficiency measures are calculated. Then, efficiency measures are regressed on farm specific characteristics to identify sources of inefficiency (Fletschner and Zepeda, 2002; Nyemeck et al., 2003; Dhungana, Nuthall and Nartea, 2004; Helfand Levine, 2004). Efficiency is typically found to be correlated with farm-specific attributes such as farm size, the farm manager's education, land titling, access to credit, employment opportunities, land quality, agro-ecological zone, and extension services. This ultimately determines the overall productivity of the farm.

According to Nerlove (1958), the supply response of any agricultural product is largely based on the expected futue prices. If farmers expect prices to be higher in the future, they tend to produce more output to earn higher incomes and vice versa if the expected prices are low. However,farmers fail to know each other's actions and end up either oversupplying to the market and in effect pushing the prices down. The prices also rise when there is less supply in the market and since this is normally at lagged period, we end up having a cobweb type of coffee production system that responds to varying prices. This indeed is a common phenomenon affecting the majority of coffee farmers in many coffee producing countries in world.

On the other hand , there is an inverse relationship between size of land holding and agricultural productivity has taken an important place in the literature of agricultural economics and agricultural development in recent decades. For various reasons farmers face different productivities of inputs as the size of their holding vary and thus, making their output/input ratio varies systematically with the size of their farms. The debate persists because no fully agreed upon consensus has yet emerged on what is the exact implication of the observed relationship and because of the possible (and sensitive) policy implication that it engenders (Bardhan, 1973; Barrett, 1994). For example, if it is due to a higher efficiency of small farms (low opportunity cost of labor, decreasing returns to scale), then addressing issues of land reform would be the straightforward implication. However, if it is a consequence of imperfect factor markets (smaller farms confront different factor prices from larger farms i.e. smaller farms face a low opportunity cost of labor and high prices of land and capital which is an inverse pattern for that of larger farms) then attention should be directed toward the institutional framework and the functioning of the rural economy. Lastly, if the relationship were a result of wrong measurement and omitted variables (cropping patterns, agro ecologic zones or region effect, etc.) then, a non-interventionist strategy would be the best alternative.

An assumption is that smaller farms will face a low opportunity cost of labor but a high price of land. This will be a result of an excess availability of family labor on one hand and constraints to access land (inadequate amount of land for optimal farm production) on the other hand. Thus we should observe rising productivities of labor and falling productivities of land as the size of the holding increases.

This theory predicts that farm productivity, measured by marginal factor products, will differ over farms using different levels of inputs; for example, marginal productivity of a given amount of labor will be greater on a farm with a larger landholding. Empirical research in developing countries tends to confirm this prediction. For example, works in India (Bardhzn, 1973; Deolalikar, 1981; Rao and Chotigeat, 1981) find that small farms have higher land productivity but lower labor productivity, especially when using more labor intensive techniques.

The inverse relationship between farm size and land productivity has been important in land reform debate in developing countries suffering growing land constraints, supporting the smallholder whose technique factor bias uses shrinking land resources more productively. For example, Ellis (1993) argues that smaller farms allocate a substantial amount of their holding to higher value crops and improve more their land (soil conservation devices and fertilization) while larger farms are more oriented toward land extensive practices (livestock grazing, trees, longer fallow) or lower value crops.

Empirical research has shown, however, that the relationship will depend on the amount of labor variable inputs that are used by farmers as substitutes of labor. For example, Adesina et al. (1994) find large rice farms more efficient than smaller ones in Northern Cote d'Ivoire as a differential access to technology. Previous public policies favor larger farms to access input and credit markets and research information more than smaller farms.

Where farmers are economically rational, and faced with perfectly functioning input and output markets, they equate marginal value products (MVPs) to factor prices. Then, where the marginal value product of a given factor is not equal to its price, it is either because the farmers are not economically-rational, or because they face an imperfect factor market which constrains their access to factors of production. Tests of the non-equality between the marginal value product and the factor price have been rare in Africa, where one might posit that only-recent commercialization of the rural economies, and underdeveloped factor markets might cause these two figures to be unequal. Carter and Wiebe (1990), for example, found them unequal in Kenya due to market failures in the system (constraints on access to capital and to land and/or constraints on labor transactions). Due to the little demand for labor outside agriculture we should expect the marginal value productivity of labor to be a fraction of the wage of labor. On the other hand, traditional land rights (inherited land cannot be sold outside the family) coupled with public laws and policies (free land transaction is prohibited) we expect constraints to access land which will make the market price of land (proxied by the rental price) be a fraction of the marginal value product of land.

Another assumption is that smaller farms have better land than larger farms and thus get higher productivities. This difference in the quality of land between smaller and larger farms will exacerbate the inverse relationship between farm size and land productivity. Effectively, changing productivity is also attributed to land degradation. Land degradation is said to affect the inverse relationship between farm-size and productivity and some authors even argue that the inverse relationship between farm-size and productivity is principally a result of the loss in the quality of land.

Bhalla (1988) showed that by controlling the effect of the quality of land the inverse relationship between farm-size and productivity weakens or disappears. Thus, knowing how land degradation (and in general land quality) affects agricultural productivity and farmers efficiency is of interest for sound policy formulation.

In Rwanda, the shortage of land has pushed farmers to crop marginal land easily degradable and long believed not suited for agriculture. Their intensive cultivation combined with non-sustainable methods of production (no or little fertilization and no or few soil conservation investments) has impoverished the land and this has affected negatively farm productivities. However, its effect on the observed inverse relationship between farm size and productivity will depend on the group (smaller vs larger farms) that has the most degraded land.

If land on smaller farms is, for example, more degraded, the potential inverse relationship will be partly offset but if they have better land, then the observed relationship will be accentuated. More explicitly, it will try to dig more into the issue of the Inverse relationship between productivity and farm-size and to tie in the effect of land quality. Bhala and Roy (1988), and Bhalla (1988) argue that conventional production function has been constantly mis-specified due to an under-estimation of the importance of agro-climatic and soil factors while they affect the observed inverse relationship. Bhalla (1988) finds a negative correlation between farm size and soil quality. Bhalla (1988) argues that once proper account is made of exogenous land quality variables, the inverse relationship is observed to weaken, and in many cases, to disappear. It is not the case, however, that no relationship remains between size and productivity-but the universality of the stylized fact is not 100%, but only 30% of the districts in India (Bhalla, 1988).

Another factor that affects the observed relationship between farm-size and productivity which is often overlooked is the crop composition of output. Sometimes, differences in aggregate productivity between small and large farms are attributed to size or returns to scale effects while in reality they are a result of the crop composition of output. Bardhan (1973) notes that if some sizes of farms tend to grow more high-valued crops, what is essentially a crop-composition effect may be confused in production function studies as a size effect or a returns-to-scale effect in production.

Ellis (1993) also agrees that among the technical reasons for the inverse relationship between farm size and productivity figure the crop composition of output. Larger farms view land as an abundant factor and thus are more inclined to underutilize it by producing lower value crops or orienting themselves toward land extensive practices than smaller farms do. As a result, smaller farms may have a higher productivity in value terms.

The agricultural supply response is influenced by the prevailing international coffee market prices, which in turn is influenced by supply or production. This can be predicted by the supply elasticity that is influenced by the long-run price elasticity. The long-run price elasticity can be estimated by the Nerlove Model.

2.2.2 Empirical Literature

A study conducted by Bardhan (1973) found a negative relationship between output per acre and farm size in both rice and wheat fields (monocrop situation) in India. Bardhan (1973) attributed the observed relationship, to the "inverse correlation between (farm) size and other inputs rather than of scale diseconomies" (p.1386). Results obtained by Bardhan (1973) showed that smaller farms use more labor input per unit of land even when there is evidence of constant returns to scale. Moreover, when Bardhan (1973) fitted an equation explaining the variations in labor use per unit of land across farms, the study found a statistically significant negative relationship between labor and net area shown.

Using cross-regional data from Indian agriculture, Deolalikar (1981) found that the inverse relationship between yields and farm size holds for traditional agriculture but does not hold for agriculture experiencing technological change. In the post-Green Revolution period, land productivity is mainly a function of inputs like fertilizer and improved seeds. However, farm inputs used by the farmers are mainly given on credit. This means that they are unlikely to be used by small farms. Land productivity is, however, less dependent on the amount of labor used.

The results by Deolalikar (1981) were confirmed by Rao and Chotigeat (1981) who showed that land and labor have a negative effect on the elasticity of gross value of output per unit of land while capital has a positive effect. According to Rao and Chotigeat (1981), the net effect depends on which of the two effects is the largest. Specifically, farms employing more hired labor and using more nontraditional inputs such as fertilizers, high-yielding crop varieties, improved ploughs and tractors, and larger holdings have higher productivities.

Feder (1985) analyzed the impact of labor supervision and credit constraint on the relation between farm size and labor and yield. Feder (1985) demonstrates that the negative relationship holds when there is high supervision cost of hired labor by family labor and when access to credit is conditioned by the size of the holding (as collateral). If markets were perfect each family would lease in or lease out as much labor as needed in order to maintain an operational holding which is proportional to the size of the family. Thus, labor input would be identical across farm and consequently yields would not be affected by farm size.

Bhalla et al (1988) incorporated the effect of land quality in their analysis of the inverse relationship between farm size and productivity. Land quality was proxied by the soil type, color, and depth in the absence of data on soil fertility. They found agro-ecologic and soil factors to be important determinants of farm productivity and hence their omission would result in specification error. The earliest studies in Africa were mainly sectoral. These studied a particular crop, which were mainly an export cash crop. Very few studies were concerned by the overall productivity of the smallholder farming.

However, several authors tried to assess the farm size - productivity relationship for smallholders (Eicher and Baker, 1985; and Ellis, 1993 for a review). Some of the recent studies are those of Blare et al. (1989) in Kenya, Barrett (1994) in Madagascar, and Adesina et al. (1994) in Cote d'Ivoire. Blare et al. (1989) observed an inverse relationship in Kenya. They find that an inverse productivity-size relationship exists as a result of market imperfections. Smallholders are limited in their access to capital while large holders are unable to access labor cheaply (i.e. at the in-house opportunity cost). The authors analyzed this fact by using a size-sensitivity analysis where they regressed the marginal value products on quadratic terms of land size. The results show that the marginal product of capital in maize-beans cultivation falls significantly as farm size increases while the marginal product of labor starts low due to intensive labor application on small farms and rises with the size of the farm.

In the author's M.A Research (1989) it was found out that coffee production technology in Kenya exhibited constant returns to scale. These results were based on Cobb-Douglas production function. This means that if Kenya wanted to double its coffee output, all it requires is to double the prescribed inputs. The study however falls short of what each factor of production contributes to the overall coffee output. This study is therefore unique as it takes us beyond the existing pool of knowledge in furthering our understanding of the extent and level of contribution of each of the factors of production in the overall coffee productivity and output in the Kenyan economy in general and that of Kiambu in particular.

In its annual publications and research reports, the Coffee Research Foundation of Kenya has largely concentrated on researching of the new coffee varieties that can produce higher yields and paid little attention to the contribution of the various factors of production that can improve overall coffee output from the country.

According to Varian (1992) one can make use of Ordinary Least Squares (OLS) Method to estimate a linear relationship between a dependent variable against several explanatory variables. Hence the linear relationship in log form between coffee output and the explanatory variables is therefore amenable to estimation by the use of the ordinary least squares technique. He however says that one may wonder whether the estimates obtained as a result of the above regression are acceptable. The answer to this question depends to the large extent on the intended use of the estimates. For instance, if we are primarily interested in forecasting the level of coffee output given a description of the inputs then the estimates derived using the above technique are acceptable. In other words, if we are just testing in this case that the above function exhibits a Cobb-Douglas production function, then the above criteria gives an acceptable outcome.

On the other hand if we are interested in estimating a relationship between coffee output and specific inputs, then the above method may give quite poor results (large standard error). Hence, individual parameter estimates and associated t-statistics do not give a precise estimation of the variance. Hence, this is likely to be the case in our results, since most, if not all, inputs are highly correlated. For instance, a larger scale farmer uses more of the farm inputs compared to a small-scale farmer. This, then means that a high level of coffee output would, require a high level of input use, and therefore, results of high degree of correlation among the input should therefore not be surprising. Because of this high degree of multi-collinearity, the above technique is not bound to give us precise estimates and in this case, ordinary least squares method has given us cold comfort for the sampling variance increase with rising collinearity among the explanatory variable. It can then be stated that a high level of multi-collinearity among the explanatory variables gives a high level of R-squared and also a high level of sampling variance.

Mwabu et al (1998), carried out a study on the effects of agricultural extension on farm yields in Kenya and 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.

Kalyebera (1999) did a study in Uganda on a comparison of factors affecting adoption of improved coffee management. The study established failed to show the contribution of individual factors of production to the overall coffee output for both small holdings and large scale farmers. Although there have been a lot of market reforms in the Agricultural sector, the production and market participation by smallholder farmers in Kenya continues to decline. Karanja (2002) carried out a research study in Central Kenya to investigate why there has been dismal performance by the smallholders. The study findings showed that constraints in factor markets, high transaction costs and risks tempered resource allocation towards subsistence production with consequent declines in productivity and market participation.

Smallholder farmers in Kenya have medium to high level of production efficiency which is comparable to the efficiency levels in other developing countries. The study, therefore, shows that smallholder-based development strategy is an efficient mode of organizing agricultural production. Further high levels of growth from smallholder farmers is likely to come by improving resource allocation and re-allocation technology.

A study by Odhiambo et al (2004) explored the sources and determinants of agricultural growth and productivity in Kenya for the period of 1965-2001. The study established that most of the agricultural growth in Kenya is attributable to factor inputs – labour, land and capital; for the entire period of study the three factors accounted for about 90% (of which labour alone accounted for 48%) of the total growth output and only 10% of the growth output was attributed to the other factors of production. The Brazil Coffee annual report (2005) was mainly concerned with coffee production, distribution and how it's traded through exportation.

The bulk of the coffee in Kenya is produced in central and eastern province. Coffee producers in central province are drawn from the following districts of, Kiambu, Muranga, Nyeri, Kirinyaga, Meru and Embu. Most of the coffee factories serving coffee farmers in central province belong to cooperative societies. These societies lack the necessary capacities, competence and governance ideals necessary to deliver efficient services and value to coffee producers (Kegode, 2005).

The cost of coffee production has been rising against a sharp decline in prices, making it difficult for coffee growers to break even. For instance, the average cost of producing a tone of clean coffee by small holder farmers increased from approximately Kshs. 32,000 in 1991-92 to 64,000 in 1997-98 while for estates, it increased from Kshs. 72,000 to 120,000 during the same period. The access to credit has been a major constraint to smallholder producers and this has affected their ability to expand production. The issues of good governance in the sector are paramount for efficient delivery of key services to producers in this region (Kegode, 2005).

According to a report published in London by Consumers International (2005), coffee is one of the largest traded goods in the world. It is produced by more than 60 developing countries and consumed mainly in developed Countries with over US$70 billion of retail sales each year. At least 14 countries depend on coffee for 10% or more of their earnings. It is estimated that coffee growing provides a livelihood for 25 million people and that in total, globally; 100 million people are involved in the sector from agriculture through processing and sale. This study shows how important and marketable coffee is but falls short of indicating which factors are critically important in its production; hence the justification for this research study.

According to a coffee baseline report by Sokoine university of Agriculture, Tanzania (2005), the main focus is on how coffee has contributed to the livelihood of the people and not very clears on the significant role the various factors of production in the overall coffee output.

According to the study carried out by Bussolo et al (2007) and published in the Journal of Agricultural Economics, impact of coffee rises on rural households in Uganda shows that more coffee production was as a result of increased farm acreage brought under coffee, meaning that the more land one allocates to coffee the more coffee output expected. The same study shows that farmers fetched higher prices based on marketing strategy and keeping high quality products. According to the study carried out by Luong and Tauer (2006) and published in the Journal of Agricultural Economics, a real options analysis of coffee growing in Vietnam found that Vietnamese growers were sufficiently efficient in producing coffee even at relatively depressed price levels.

In view that farm size has been mentioned in influencing coffee output in Uganda, it is important to extend the same analogy and assess how fertilizer and spray chemicals contribute in changing these outputs at individual factor level. This study will therefore look and clearly come up with the extent to which each of the three factors cited influence coffee production at the individual level and in a key coffee producing county in Kenya.

A study done by the Federal Ministry for Economic Cooperation and Development Germany (2007) focused on how climate changes affect coffee production. Nchare

(2007) carried out a study on the analyses of the factors influencing the technical efficiency of Arabica coffee farmers in Cameroon; to carry out this analysis, a translog stochastic production frontier function, in which technical inefficiency effects are specified to be functions of socioeconomic variables, was estimated using the maximum-likelihood method.

The findings showed some increasing returns to scale in coffee production. The analysis also revealed that the educational level of the farmer and access to credit are the major socioeconomic variables influencing the farmers' technical efficiency. The findings also proved that further coffee productivity gains can be realized by improving technical efficiency.

A research compiled by Omwoyo (2008) dealt with assessing the effect of Coffee production on Abagusii women in Western Kenya during the period 1900-1963. Mureithi (2008) found out that many cooperative societies in Kenya are not well managed: cost overruns by cooperatives are recovered from members who end up receiving very low net payout. As a result of this, attaining decent work standards in the coffee sector poses a major challenge. However, the infrastructure for decent work is in place and delivering where possible.

A study by Condliffe et al (2008) on Kenya Coffee focused more on how coffee is produced based on a Cluster Analysis. The study recommended that Kenya should focus on three areas to improve the competitiveness of its coffee cluster. These are creating a differentiated coffee strategy; improving the functioning of the value chain by increasing competition, clamping down on corruption, and reforming governance structures; and addressing the disruptions created by liberalization of the sector in the 1990s, such as managerial voids in cooperatives and reduced access to credit and agricultural inputs for farmers.

A study by the Department of Economics, Lund University, Sweden (2009), focused on coffee gains from its marketing in Ethiopia and never studied the contribution of factors of coffee production. A study by the Centre for Agricultural Research and Ecological Studies (CARES) Hanoi Agricultural University, Vietnam (2009), researched on the application of microbial organic fertilizer for safe coffee production. The study did not consider other factors of production.

Mulwa et al. (2009) on smallholder maize farmers in western Kenya studied economic efficiency in agricultural production applying the two-step methodology where firstly, a Data Envelopment Analysis was used to estimate farm efficiencies, after which selected farm and farmer attributes were regressed in a Tobit model against the estimated efficiencies. This methodology is similar to the approach by Krasachat (2007) among Thai cattle farms. Mulwa and others found that maize production in western Kenya was highly inefficient and there was room for improvement. It was further found that overall efficiency was significantly affected by the quality of seed used and household size.

Mulwa et al. (2009) observed a negative coefficient for household size, suggesting that the larger the household the lower the overall efficiency. The authors argued that larger households had the potential for providing cheaper farm labour. However, the funds that would have been used to purchase other farm inputs is often allocated to some other necessity like household consumption, hence the negative effect on overall efficiency. It was established that bean productivity was significantly influenced by plot size, ordinary seeds, certified seeds and planting fertilizer; all of which had a positive effect as hypothesized.

Winter et al (2010) did a study on Marketing boards and market power on the Kenyan pyrethrum. The research focused on how Countries with market power must first select export levels that account for both the elasticity of demand and the possibility of inducing persistent shifts in demand and then stimulate producers to supply appropriate quantities. In Africa, marketing boards usually determine export and production policies. Analysis of a marketing board's problem in this situation requires a multi-period perspective that treats demand endogenously and accounts for the dynamics of supply response. Because it has failed to keep production aligned with demand, Kenya has probably suffered through its power in the market for pyrethrum (a natural insecticide).

Winter et al (2010) asserted that, although Kenyan pyrethrum export levels influence world prices, the country has not controlled local production reliably. Retrospective analysis indicates the shortages in Kenyan pyrethrum stimulate the development, licensing, and commercial use of synthetic substitutes. Once these substitutes become available, the market for pyrethrum is reduced persistently. Export policy is fundamentally constrained by farm production. Because the Pyrethrum Board of Kenya (PBK) purchases all Kenyan pyrethrum, production decisions are related to farmers' perceptions of the PBK. Analysis of supply response indicates that farmers' estimates of the financial strength of the board (based on past performance) significantly influence production. Consequently, production levels respond to performance in the world market while they constrain marketing options. A stochastic dynamic programming approach that accounts for farmers' perceptions of financial strength and for persistent substitution as an endogenous factor provides a consistent framework to guide policy for the PBK. Alternative analyses that ignore induced entry or underestimated supply elasticity significantly overstate the possible benefits of applying market power. Even as the analysis of Kenyan pyrethrum indicates policy options for that industry, it illustrates the importance of inter-temporal supply and demand responses to policy initiatives in many other industries.

A study by Sao Paulo State University (2010) focused on weed interference in coffee fruit production. A research by Lemes et al (2010), aimed at investigating the effect of weed on coffee fruit production and came up with measures that can be used in controlling the weeds. This study would like to show whether spray chemicals can control weed and increase productivity of the crop in Kiambu County in Kenya.

Derege (2010) carried out a study on the analysis of factors affecting the technical efficiency of coffee producers in Jimma zone in Ethiopia. The study examined possible reasons for low productive performance of coffee using cross sectional data gathered from Jimma zone. An attempt to measure technical efficiency of coffee producers, analysis of its determinants and the impact of various distributional assumptions on technical efficiency estimates were made. The result revealed that various distributional assumptions of technical inefficiency have approximately similar impact on technical efficiency estimates. On average, coffee producers are 72% efficient, implying that there is ample opportunity for these farmers to raise output level at present technology. There is also advantage of scale economies linked to increasing returns to boost output. Except fertilizer, overutilization of other inputs leads to inefficiency.

Henning (2010) did a research on the relationship between the farm size and productivity in the South African Land Reform. The study considered both small and large scale farmers. It concluded that the relationship between land yield and farm size was negative. This implied that small-scale farmers are more productive than large-scale farmers. This research confirmed what other previous researchers such as Masterson (2007), and Thapa (2003; 2007) had found.

The International Trade Centre (2010) notes that climate change is one of numerous factors that affect global coffee production, especially from smallholders (who produce the majority of the world's coffee) and who are the most vulnerable group; this group of coffee producers is least equipped to cope with it. Complexity and uncertainty make it hard to be precise, but it is generally accepted that climate change will affect both Arabica and Robusta producers. Rising temperatures are expected to render certain producing areas less suitable or even completely unsuitable for coffee growing, meaning production may have to shift and alternative crops will have to be identified. Incidences of pests and diseases will increase, whereas coffee quality is likely to suffer, both factors that may limit the viability of current high quality producers. More coffee may need to be grown under irrigation, thereby increasing pressure on scarce water resources. All the foregoing will increase the cost of production, whereas in the future fewer parts of the world may be suitable for coffee production. If so then the already evident growth in concentration could become even more pronounced, bringing with it an increased risk of high volatility. For example if an extreme event should severely curtail the output of one of the major producers.

In research done by the Ethiopian Institute of Agricultural Research (2011) on Arabica coffee and development intervention to improve coffee production and productivity in Ethiopia, it is found that Ethiopia is the centre of origin and diversities of Arabica coffee. This has boosted the country in its social, economic and social aspects. Despite the challenges, the research institute has done ample research and has come up with development strategies aimed at improving coffee production in this country.

Chen, et al (2011) in their research study of examining the empirical relationship between farm productivity and farm size in China's agriculture, observed an inverse relationship between total grain output and cultivated area. However, after they used econometric methods to control for unobserved land quality, the inverse empirical relationship between grain output and cultivated area disappeared, and concluded that farm output is proportional to farm size in China. Generally this theory of inverse relationship (IR) has not been fully accepted. They therefore suggested that further research should be carried out to examine the effect of farm size on total factor productivity.

There is therefore a large amount of literature on the inverse relationship (IR) between land productivity and farm size, and several papers have concluded that there is a significant IR. This study research was, therefore, to examine the effect of farm size on total productivity of coffee production in Kiambu County in Kenya, and probably conclude this debate on IR.

Okoboi (2011) carried out a study to examine the factors that influence farmers use of improved inputs (improved seed, fertilizer, fungicides/herbicides and traction) in maize production. The relationships between improved inputs use and productivity, and commercialization in maize production were also examined in the study. Three econometric approaches, namely: Multinomial Logit Model (MLM), Stochastic Frontier Analysis (SFA) and Tobit Model were used to examine these relationships; using Uganda National Household Survey (UNHS) 2005/06 data, collected by the Uganda National Bureau of Statistics (UBoS).

The study findings revealed that the majority of farmers in Uganda do not use improved inputs in maize production. The results suggested that the level of fertilizer and traction use had a remarkably positive effect on yield and labor productivity but not gross profit. The marginal Labor productivity value of maize production was found to be lower than the community wage rate. Finally, the results indicated that the pattern of commercialization of maize producers was not explained by the level of use of improved inputs. Instead, commercialization was highly influenced by area cultivated, grain price and yield.

Mugweru (2011) carried out a study to assess the determinants of coffee production in the Kenyan economy. The study found out that there is a positive relationship between price and coffee output. The findings also indicated that coffee output has a positive and statistically significant relationship with hectarage planted; an increase in hectarage leads to an increase in coffee output (Tonnage). However, the results indicate that there is a negative, but statistically insignificant relationship between coffee output and rainfall further implying that an increase in rainfall beyond the level of 2500mm and a drop in rainfall below 1000mm lead to a drop in coffee output (Tonnage). The findings further reveal that there exist a positive and statistically significant relationship between coffee output and price of input (fertilizer). However, the relationship between coffee output and credit advanced is negative but statistically significant. The study shows that the relationship between the hectarage planted and coffee output is positive and statistically significant.

A research done on culture of coffee in Guatemala states that Guatemala being one of the World's leading coffee producers, markets its coffee in those countries with strong economies like U.S and Europe. A research by Australian Coffee Growers (2011), on coffee growing conditions was done to determine the type of soil and correct temperature necessary for coffee growing. A research on coffee production by Wikimedia inc. (2011) in Kerala, South India states that it is mainly dominated in three regions forming the traditional coffee growing region of South India.

A study by Theuri (2012) investigated challenges affecting revitalization of coffee which included, access to coffee market, funding of coffee, management of coffee cooperatives societies and gender issues influencing coffee revitalization programme in Mukurweini district in Kenya. This study found out that coffee farming is a male dominated activity with most coffee farmers aged over 51 years. Men dominate in decision making on the scaling activities, ownerships of the coffee crop, access to credit for coffee development, labour provision and control coffee income.

It was also found out that women had significant influence on coffee production and that women representation in management committees is low and not in key decision making positions. The study also found out that credit accessibility is important to coffee farmers for coffee improvement. Marketing of coffee has a strong influence on coffee revitalization and thus favorable marketing conditions are needed to enhance access to market. This study found out that the management leadership style was good, committed towards management of coffee society as a business and also influences coffee revitalization. It has been shown that declining productivity of coffee is partly due to low use of inputs, marketing problems, poor governance of cooperatives and international marketing conditions (Theuri, 2012).

Gathura (2013) carried out a study to determine the factors affecting small scale coffee production in Githunguri District, Kenya. The research established that marketing factors, finances, government policies and physical and human resources greatly affected coffee production. The study recommended that the government should encourage coffee production by formulating favorable marketing factors and other policies and provide financing to small scale coffee producers. Producers, on the other hand should strive to provide a conducive working environment to their workers so as to sustain them in their farms. This will help to improve coffee yields and quality.

Bichanga (2013) carried out a study to find out the effects of liberalization on the production of coffee in Kenya. The main objectives of the study were to find out how, removal of government controls, takeover of societies’ management by farmers’ committees and the removal of monopolies in the processing and marketing affected coffee production Kenya. The research findings were that Liberalization of the coffee sector resulted in decreased production of coffee. The reasons cited for the decline in coffee production included: the mismanagement of co-operative societies; decline in application of inputs; poor farming practices; and farmers' loss of confidence in management of coffee affairs. Interest in the inverse relationship between farm size and productivity arose in the1960s out of the observation that for Indian farms, yields are inversely related to farm size (Bardhan, 1973; Rao and Chotigeat, 1981; Deolalikar, 1981). 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. They can be classified in a number of categories.

First the observed relation can be a consequence of market failures (imperfections), which is a state where neither participant face in practice competitive markets. Since shadow prices of factors of production vary with the size of the holding, farmers will apply more of the factor to which they have easy access, for which they face a very low shadow price (Blare] et a1., 1989). An example is the presence of a dual labor market where smaller farms face a cheaper imputed labor cost (Feder, 1984). Smaller farms apply labor until its marginal value product becomes a fraction of the market wage (Wiebe, 1990). Thus, farmers get a higher labor/land ratio and therefore a higher per-acre yield.

Second, the relationship can be a consequence of decreasing returns to scale. However, production function estimates in developing countries have usually showed that returns to sca.e are nearly constant (Bardhan, 1973; Barnum and Squire, 1978).

Third, the relationship can be a consequence of a superior efficiency of smallholders with respect to the intensity of utilization of land as a resource. This includes land use intensity whereas larger farms underutilize their land (they do not farm all the available land); the cropping pattern (crop composition), where smaller farms allocate a higher proportion of their holding to high value crops that usually make use of a substantial output of their labor force; land quality, where smallholders improve their land (soil conservation investments, manure, mulch) more than do large holder; and multiple cropping, which is mostly used by smaller farms.

Fourth, there are other factors usually grouped in a region-specific variable. The most common factors are soil fertility or quality, where a region with better land attracts more people; and difference in prices and wages, where for example regions of higher wages attract more settlers (Bhalla and Roy, 1988; Bhalla, 1988). For example, Barrett (1994) shows that the observed relationship in Madagascar is a result of the risk in prices faced by farmers.

2.2.3 Conceptual Framework

The conceptual framework developed in this study was mainly intended to determine a set of one or more factors of coffee production that will bring about optimal levels of coffee output for small holdings farmers in Kiambu County.

The analysis of input preference and usage is grounded in the theory of utility maximization. It is postulated that farmers would prefer the use of an input as long as the utility derived from the application is greater than that of other inputs. Since we cannot observe internal decision-making processes of the farmer, what we observe is application or non-application of some inputs. In this case farmers are categorized in binary classes where they either use some inputs or not and in specified quantities per acre of land. This has largely formed the basis of widespread use of binary choice models, generally the logit and probit models. These models are appropriate in the analysis of production factors and in this case size of land, fertilizer and spray chemical input use in the coffee production.

It is conceptualized that use of inputs is a function conditioned by a set of farmer/farm and institutional factors that influence farmer decision-making. Farmer/farm factors include education, gender and age of household head, opportunities for off-farm job, family structure and income from other enterprises. Institutional factors include land tenure system, extension services and farm size. These circumstances differ from one household to another and it is important to examine whether these circumstances differ between users of inputs and coffee output and those that do not use any or any of the inputs. This way we can be able to know which of the inputs mentioned play a significant role in coffee production. This requires that we categorize coffee farming households into users of some inputs and those that do not and assess their socioeconomic characteristics. It is necessary to determine factors which increase the likelihood of using some inputs.

An important conceptualization of this study is that preference of an input usage is not an end in itself. That is the utility of the farmer is not only maximized by application of an input, but also by the achievement of set objectives or outcomes. Farmers use inputs in order to achieve some objectives, some are subjective and others are objective. Some objectives for using some inputs include improved quality of coffee berries, increased productivity and profitability of coffee. This study therefore provides an opportunity to examine which factors play a significant role in both coffee productivity and profitability.

Conceptual Framework of the Study

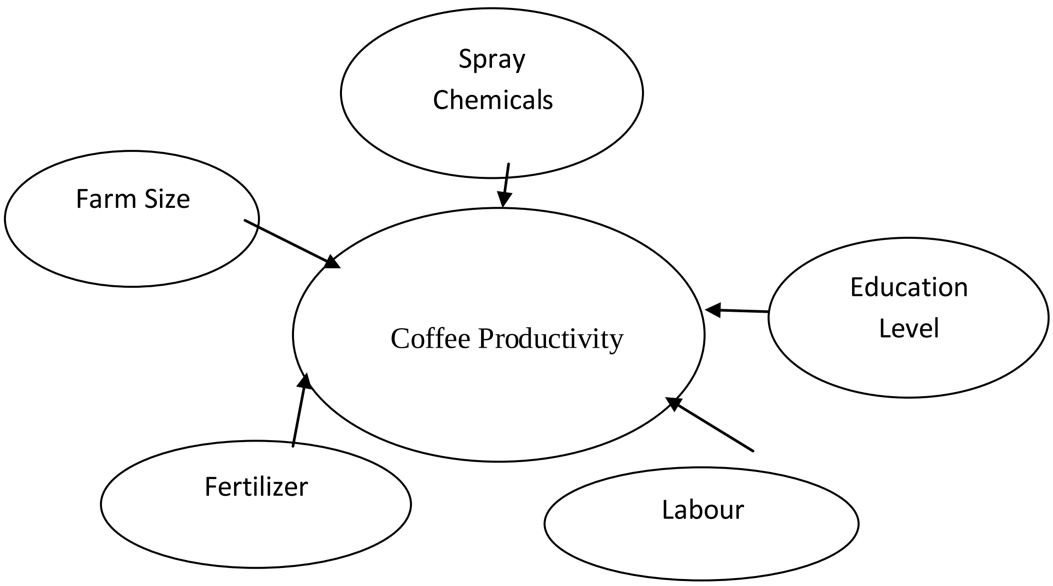

Figure 2.2: An Illustration of some Selected Factors Contributing to Coffee Productivity
Source: Author

The smallholder coffee enterprise in Kenya poses a major difficulty in analysis because coffee farming has suffered grossly from persistent declines in international coffee price. In response to declining coffee prices farmers reacted differently thereby creating a myriad of classes of coffee farmers with a high degree of heterogeneity. The main classes of farmers include neglected farms, farms where coffee was interplant with food crops, open coffee and coffee/agro forestry practices. In addition, there were fields where coffee trees were cut so that farmers could allow stumps to regenerate and mature if prices were to improve.

Neglected farms and farms where the stumps are in their formative years of regeneration were characterized by low productivity and profitability. This implies that to measure productivity and profitability of coffee including outputs from such farms can lead to misleading results. Furthermore, farmers do harvest some output even on untended farms due to the inherent fertility of the soil and ample rainfall in the coffee-growing highlands of Mt Kenya. We therefore need to measure productivity of coffee farms where farmers actively tend their crops but make use of data from all farmers.

There is no policy guideline on acceptable productivity per hectare especially under adverse farming conditions and therefore we envisaged that farmers who achieved above the sample mean were the active farmers for whose productivity and profitability we wish to measure. The mean cut points for productivity and profitability of coffee were thus used to delineate productive versus non-productive farms as well as profitable versus non-profitable farms. The mass clustering of values around the cut points makes the Tobit model appropriate for analysis of productivity and profitability of coffee in such circumstances. It should be appreciated that the Tobit model makes use of all the sample information and it is the suitable regression model for analysis where there is censoring.

Productivity and profitability are joint outcomes of the same production process. However, researchers do not consider whether the two outcomes face similar incentives/disincentives. Complementarity is defined here as a relationship between two outcomes, productivity and profitability, such that the direction of influence of the determinant is the same for both outcomes. Knowledge of such interaction is useful in prioritizing those determinants that are likely to be sources of incentives for both policy objectives of increased productivity and profitability of an enterprise, coffee in this case.

There is literature on the economics of complementarity (Johnson and Masters, 2004; Khanna, 2001) but previous research has not addressed the complementarity between determinants of two outcomes, such as productivity and profitability, of an agricultural enterprise. This study assessed for complementarity between determinants of productivity and profitability of coffee enterprise. The underlying hypothesis of the study was that determinants of productivity of coffee exhibit complementary relationship with determinants of profitability.

2.2.4 Concluding Remarks

It can be deduced from the aforementioned researches that a lot of work and research have been done on coffee and coffee products in general; however, literature on how individual factors of production contribute to overall coffee productivity is scanty.

This research study, therefore, focused more specifically on a main coffee producing county in Kenya, Kiambu, and considers three most important factors of production that determine the overall coffee output and its productivity in Kenya. The findings of this research are likely to help policy makers to make informed policy decisions in allocating resources to the use of the most economic input or combination of inputs that will yield highest returns. This research is also likely to address the problem of supply response to international price variations by enlightening farmers on international market signals of coffee output and prices based on lagged trends.

2.3 Supply Response

Supply response is a reaction on the part of the suppliers of goods and services in controlling and regulating the quantities of the same goods and services supplied based on the changes of their prices or changes in inputs' costs.

2.3.1 Theoretical Framework

In theory, 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. Initially the Nerlovian model was useful when applying it to annual crops in which long lags were missing. The model's success for annual crops was not enough ground for its use for perennial crops where long lags are anticipated.

It is noted that having few lagged price variables in a supply response model, is not sufficient for certain crops, since the entire effect of a price change on output cannot be expected to show up only in one or two periods. For perennial crops, the effect of a price change on output is spread over many years. A price increase may influence a farmer to grow new plantings, which would come into production only after some years. The farmer may also be motivated to increase supply by giving greater attention to cultivation aspects such as pruning, weed control, crop protection, and more complete harvesting. Some of the impacts of this better care for mature trees on output are spread over the entire life of the tree.

Kulshreshtha (1976) also noted that the farmers' decisions are affected by technical, institutional and psychological factors. These factors give rise to a gestation period. The researcher noted that in the presence of a gestation period one would not expect the supply to change immediately following a change in price. This leads to the notion of a distributed lag relationship between output and the prevailing market prices.

On the other hand, the polynomial distributed lag formulation of price expectations allows the weights assigned to past prices to first increase and then decrease. Such a model specification appears to be more realistic than the Nerlovian model since the shape of the response function is not restricted to any pre-assigned shape. However, the model has both conceptual and statistical challenges. It is also noted that farmers' focus on quantities of output and variable inputs based on the popular assumptions of profit maximization and their price taking behaviour as well as the concavity of the production function in the variable inputs. In this regard farmers become price takers in both the input and output markets, that is, there is no production group that is capable of exercising monopolist behaviour in the input market or monopolist behaviour in output markets. The long-run static profit function is then defined at the industry level by using data of the variable inputs and outputs aggregated across all the farms since Input and output prices are taken to be the same for all the farms.

A good number of researches and studies of supply response for perennial crops have used linear or log-linear functional forms. These functional forms imply extremely restrictive production functions and behaviourial relations. Use of flexible functional forms for production functions permits the imposition of less restrictive assumptions about the nature of technology than do popular production functions form such as Cobb-Douglas and Constant Elasticity of Substitution (CES).

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.

This model is based on a time lag between supply and demand decisions; agricultural markets are a context where the cobweb model might apply, since there is a lag between planting and harvesting (Kaldor, 1934, p. 133-134). If there is unfavourable weather, suppliers take a minimum amount of their goods to the market. This shortage, which is equivalent to a leftward shift in the market's supply curve, results in high prices. If prices continue to rise, then in the following period, they will raise the supply of the same product relative to other products. When they go to the market the supply will be high, thus pushing down prices. If they then expect low prices to continue, they will decrease their production of their product for the next year, resulting in high prices again.

The cobweb model in this case can then have two types of outcomes:

If the supply curve is steeper than the demand curve, then the fluctuations decrease in magnitude with each cycle, so a plot of the prices and quantities over time would look like an inward spiral, which is referred to as a stable or convergent condition. If the slope of the supply curve is less than the absolute value of the slope of the demand curve, then the fluctuations increase in magnitude with each cycle, so that prices and quantities spiral outwards. This is called the unstable or divergent condition.

Two other possibilities are:

Fluctuations may also remain of constant magnitude, so a plot of the outcomes would produce a simple rectangle, if the supply and demand curves have exactly the same slope.

If the supply curve is less steep than the demand curve near the point where the two curves cross, but more steep when we move sufficiently far away, then prices and quantities will spiral away from the equilibrium price but will not diverge indefinitely; instead, they may converge to a limit cycle. In either of the first two scenarios, the combination of the spiral and the supply and demand curves often look like a cobweb, hence the name of the theory.

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.

In the stable case, this may not be an unbelievable outcome, since the farmers' prediction errors (the difference between the price they expect and the price that actually occurs) become smaller every period. In this case, after several periods prices and quantities will come close to the point where supply and demand cross, and predicted prices will be very close to actual prices. But in the unstable case, the farmers' errors get larger every period. This seems to indicate that adaptive expectations are a misleading assumption—how could farmers fail to notice that last period's price is not a good predictor of this period's price?

The fact that agents with adaptive expectations may make ever-increasing errors over time has led many economists to conclude that it is better to assume rational expectations, that is, expectations consistent with the actual structure of the economy. However, the rational expectations assumption is controversial since it may exaggerate agents' understanding of the economy. The cobweb model serves as one of the best examples to illustrate why understanding expectation formation is so important for understanding economic dynamics, and also why expectations are so controversial in recent economic theory.

2.3.2 Empirical Literature

Chhiber (1989) noted that non-price factors mainly technology, infrastructure, research and extension are more important mechanisms in increasing supply response and sustaining agricultural growth. The study demonstrated that the aggregate supply elasticity with respect to prices in many sub-Saharan African countries lies in the range of 0.3 to 0.9, partly due to inadequate supportive infrastructure, imperfect markets and lack of capital.

Supply response in these countries may be minimal because the subsistence sector is assumed to be risk averse and also farmers are assumed to have income targets such that if the producer price increased, the production of smaller amounts of a commodity would provide the necessary income. A key expected consequence of market liberalization was that farmers could respond positively to the expected price incentives by increasing supply.

A study by Fosu et al, (1990) analyzed the performance of Ghana's agricultural sector under structural adjustment. The study found out that agricultural supply response had been constrained by high costs of improved technology such as fertilizer, pesticides, irrigation, agricultural mechanization services, inadequate public agricultural expenditure, the extremely low capacity of the private sector to take up the delivery of these technological packages, high cost of agricultural credit and labour and stiff competition caused by trade liberalization.

Pearce (1992) notes that the price of export crops relative to import-competing crops (specifically, maize and rice) and the price of export crops relative to non-traded crops (starchy staples) increased during 1983-87. As a response, the output of export crops (specifically cocoa) tended to increase during the period.

A study by Fosu (1993) examined the mechanisms through which specific sectoral and macro-economic policies have influenced the agricultural sector. This study concludes that, during the structural adjustment era, public expenditure policy was restrictive, and the growth rate of public expenditure declined.

A study by Ongile (1997) in Kenya investigated how gender related factors influenced adoption, and the supply response of tea production among male and female smallholders in Kenya in the period 1985/86 to 1995/96. The study established that productivity was negatively related to presence of children under five and households being headed by a widow, reinforcing the findings on the importance of constraints faced by women farmers. This by extension affected output from the affected tea firms.

A study by Bloom et al (1998) investigated other factors that influenced agricultural supply response. The study found out that natural conditions such as low soil fertility and irregular rainfall further contributed in lowering the price elasticity of supply, especially in case of severe drought.

Soderlund et al, (2001) did a research on why both domestic and international factors contributed to the decline in coffee production. A case in mind was the collapse of the international coffee agreement in 1989 as one case that destabilized the world prices for coffee. The study found out that this decline was attributed to higher prices on farm inputs, wages, fuels and interest rates, lack of access to credit to short-term working capital needs and long-term investments, low coffee payments due to high processing and marketing costs.

Danielson (2002) analyzed the relationship between individual and aggregate crops production and farm-gate prices. This study finds out that farmers in Mozambique were responsive to price incentives but structural constraints in the agricultural sector barred improved incentives being translated into agricultural growth. These structural constraints identified include lack of development finance, lack of markets, and lack of communications infrastructure.

Akanni et al (2002) did a study on Analysis of aggregate output supply response of selected food grains in Nigeria. The study found that domestic producer price support policy, such as a guaranteed minimum price policy can enhance domestic supply of food grain in the country. Critical evidence in their study was the significant but inverse relationship between output supply response and import quantities for all the crops. This shows that an unregulated importation tends to discourage domestic production of all the selected crops. Thus, some kinds of domestic support such as imposition of higher tariffs on imported food grains and effective control of smuggling are critical in stimulating domestic production of the crops. The need for government to be more firm in the control of rice and maize importation is obvious.

Rockström et al (2003) noted that suboptimal performance of rain-fed agriculture is not necessarily due to low physical potential, but primarily to management related issues. Thus, the majority of smallholder farmers remain engaged in subsistence agriculture using traditional methods as most modern technologies and innovations are not accessible and thus highly irrelevant to them. Increases in food production in the recent past in SSA are a result of more land being brought into production rather than higher output per unit area.

Cabanilla, et al (2003) did a research on crop variety improvement and its effect on productivity and supply response focusing on in the production of rice. The study found out that substantial additional benefit to regional rice productivity was attributed to crop husbandry, fertilizer application and timing recommendations for irrigated and lowland rice.

Rockström et al (2003) researched on what contributed to sub-optimal productivity an overall output supply of rain fed agricultural products. The study found out that suboptimal performance of rain-fed agriculture is not necessarily due to low physical potential, but primarily to management related issues. Thus, the majority of smallholder farmers remain engaged in subsistence agriculture using traditional methods as most modern technologies and innovations are not accessible and thus highly irrelevant to them. Increases in food production in the recent past in SSA are a result of more land being brought into production rather than higher output per unit area.

Nyangito et al., (2004) found out that trade policy can also affect growth, productivity and supply response through the foreign exchange market. This is through two hypotheses on the relationship between the exchange rate and productivity. The first is the so-called exchange-rate-sheltering hypothesis which states that a depreciating real exchange rate reduces growth in domestic productivity because it shelters domestic producers from foreign competition. This reduces their incentive to make productivity enhancing investment.

The second hypothesis is the factor-cost hypotheses, which stipulates that movements in the real exchange rate affect the absolute and relative cost of new capital and labor, therefore influencing both total factor productivity and labor productivity. Depreciation can also reduce growth, and an overvalued exchange rate can sometimes contribute to productivity growth by forcing productivity gains in the tradable sector.

Bagamba et al (2004) researched on the determinants of resource allocation in low input agriculture in Uganda using banana production as a case study. The study found out that the production function showed positive and significant relationship between banana production and elevation, crop sanitation labour and natural pasture.

Education of household head was negatively related to output, implying that improvements in education results to a withdraw labour from agriculture to other activities. Labour use in cooking banana responded negatively to wage rate but response to price was not significant. Nonfarm self-employment was negatively related to labour use in cooking bananas implying withdraw of family labour from farm production to non-farm production. There was a negative relationship between distance to paved roads and labour use, which implies higher transaction costs for farmers staying far away from improved road network.

The study by Bagamba et al (2004) also found that the education of housewife was positively related to labour used in banana production in low altitude areas but not significant for high altitude areas implying that women have a big role in decisions regarding food crop production. Investment in education (improving farming skills) of women might increase food security in low input agricultural areas. The joint effect of household characteristics on labour use (output supply) was significant implying that the separability condition between production and consumption decisions among smallholder producers is not valid. The results indicate that, given the current environment constraints, investment in technology development and dissemination has positive implications for agricultural development in low input systems. Investment in human capital, especially in education of women, and providing an enabling environment for easy access to input markets play major roles in improving agricultural production. They also observed that the driving factor in resource allocation decisions by these households is most likely to be quantity rather than preferences (taste), and thus decisions are made in favor of crops that have higher productivities in relation to labour input and land.

Elbeydi et al (2005) did a research to measure the Supply Response Function of Barley in Libya, while identifying the behavior of Libyan barley market during the period 1980-2005. The results showed that barley acreage in Libya was responsive to domestic price. This implies that price can be used as instruments to maintain favorable acreage planted.

The results further showed that long run equilibrium relationship exists between barley area planted and barley price, and wheat price. The results also show that the influence of relative price is significant in affecting barley area planted. This means that if the price is enhanced, production of barley might improve considerably. The results also show that barley area is significantly responsive to the wheat price. Policies such as price support are significant variables in influencing barley area planted. In spite of the noticeable increase in the production of barley during the period of study, as a result of the rise of level of productivity and the admission of some categories with high productivity. However, in the frame of increase production for opposite increased size of demand of barley in the local market, governments can subsidize barley farmers through some agricultural marketing policies, for instance by purchasing their production at higher prices.

A study by Monchi et al (2006) on the relationship between government and agricultural production found out lack of a stable political environment adversely influences increases in food production via production inefficiencies and attenuates competitiveness. Hence, good governance" and democracy are not simply desirable but essential conditions for development in societies.

A study done by Abra (2007) in Ethiopia examined the impact of technical inefficiency on the response of small holder farmers. The study found that technical inefficiency generally increased the magnitudes and the statistical significance of own price elasticities, substantially so in the case of fertilizer inputs. The results indicate that farmers responded positively and significantly to price incentives. The results also underscored the need to improve farmer's access to better quality land, farm inputs and credit, and public investment in roads and irrigation.

A study by Tanui (2009) did research on global tea price volatility, coping strategies, and China production. He found that falling prices did not necessarily prompt the expected supply response. The perennial nature of the tea crop means that adjustment to the scale of production through diversification and exit from the industry is slow. In the short run the price elasticity of supply appears to be very small and supply responses to price incentives are asymmetric whereby periods of rising prices stimulate new plantings and other fixed asset investments. Supply responses to falling prices have also been slowed in some cases by government's efforts to assist producers through price support. In the short-term, adjustments can be made to reduce application of inputs like fertilizer and labour which leads to unemployment.

Nsibirwa (2009), investigated on factors that caused coffee productivity and output stagnation. His findings concluded that, for coffee productivity and production to respond better the strategy must go beyond delivering better Good Agricultural Practices (GAP) and disease control to addressing the issues identified to have a wholesome approach. Coffee has to be brought back on the national political agenda to receive the appropriate funding and support; a champion must be identified for the industry, new areas must be identified and supported to grow coffee to recover land lost to urbanization and industrialization, irrigation must be part of GAP to address the devastating effects of drought, programs to get the youth back in coffee production must be designed and implemented, medium and larger coffee farmers must be supported with incentives like in other coffee producing countries, gender issues have to be addressed to establish equity to ensure sustainability in coffee production and productivity.

Rios et al (2009) investigated why higher farm sales lead to higher agricultural productivity and high output. The study findings concluded that increases in agricultural marketing may be productivity-enhancing over time, as suggested by Zhang and Fan (2004). The study further found out that firms with high productivity become exporters whereas participation in the export market does not lead to productivity growth (e.g. Bernard and Wagner 1998; Bernard and Jensen 1999).

A study done by Olwade et al (2009) assessed how responsive maize output was to price and non-price factors and how sensitive fertilizer and labour demand are to prices and non-price factors using crosssectional farm-level data for 334 maize producing households in the High potential Maize Zone of Kenya. The study found out that maize price support is an inadequate policy for expanding maize supply. Fertilizer use was found to be particularly important in the decisions on resource allocation in maize production. Of the fixed inputs, land area was found to be the most important factor contributing to the supply of maize.

Thuku et al (2010) did a study on the response of the effects of reforms on productivity and supply response of coffee in Kenya. The study found out that prices are the channel through which market reform policies affect agricultural variables like output, supply, exports and income. Market liberalization in developing countries maintains that pricing policies were biased against agriculture. Therefore, the study advocates setting of the right price as an effective mechanism to increase supply response and subsequently expand agricultural growth. The study hypothesized that reforms that offer price incentives and promote efficient marketing encourage producers to respond by increasing supply. Whereas their study argues that the “right” price would offer incentives for adoption of agricultural technologies that enhance production.

Adeleke et al (2010) did a research on trends, constraints and opportunities on Smallholder Agriculture in East Africa and classified these countries as agriculture-based. Agriculture is dominated by smallholder farmers who occupy the majority of land and produce most of the crop and livestock products. The study found out that the key long-standing challenge of the smallholder farmers is low productivity and low output supply stemming from the lack of access to markets, credit, and technology, compounded by the volatile food and energy prices and the global financial crisis. Despite the number of sound agricultural policies adopted by most countries, implementation had also been lagging. Moreover, growing disenchantment of some donors with the sector amplified the gap between policy formulation and implementation. Continued involvement of a few donors, including the African Development Bank (AfDB), notwithstanding, investment in agriculture has suffered from a declining trend in several decades before the crisis.

The surge in food prices as well as the need for greater diversification towards domestic-oriented production brought about by the financial crisis could serve as a wakeup call for the sector to receive due attention, given its importance and untapped potential. The study concluded that concerted efforts of all stakeholders, including governments, NGOs, and development practitioners are needed to remove the existing bottlenecks to productivity growth in smallholder agriculture and progress with the region’s development agenda.

Bakhtawar et al (2010) analyzed the acreage response of maize with respect to price and non-price factors in Khyber Pakhtunkhwa using the time-series data for the period of 35 years (1976-2010) pertaining to, maize area, maize price, rice price, maize yield, average rainfall. The study found out that farmers were reluctant to make larger adjustments in the main cereal crops, which are used for self-consumption.

Njaramba (2011) did a study on factors that determine coffee supply from Kenya to the international market. The study 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. This explains why the increase of prices did not stimulate production in Kenya. The researcher, however, found out that the exchange rate had insignificant effect on coffee supply from Kenya in the short run but was statistically significant in the long run. This is unlike many studies that indicated that prices offered have significant effect on coffee supply and that exchange rate policies led automatically to improved coffee supply in the short run.

Leechor (1994) in a study on the policy impact on agricultural supply response in Ghana noted that supply response in Ghana during 1983-91 was limited, and largely occurred outside the agricultural sector. Leechor (1994) indicated further that agricultural growth had been sluggish and uneven, and at a pace well below the rate of growth in the rest of the economy. Agriculture contributed only 5 percent to economic growth, whereas industry and services contributed 18 and 77 percent per annum respectively, during this period. Leechor (1994) observes, just as the aforementioned studies, that the depreciation of the exchange rate coupled with the gradual reduction in the implicit cocoa export tax stimulated an increase in the domestic producer price of cocoa. The real cocoa producer price, however, declined after 1988, and with this, brought about a fall in cocoa output. The world price of cocoa tended to decline after 1988.

Leechor (1994) also notes that real food prices (cereals and root crops) declined gradually during the adjustment period. In addition, wide marketing margins that characterized food trade during this period were due to inadequate infrastructure such as feeder roads, domestic marketing facilities and critical linkages with external markets. These factors also tended to limit the scope for private investment in agricultural product and input marketing. Leechor (1994) concludes that farmers in Ghana respond significantly and promptly to price changes. This assertion is based on two supply response regression equations for cereals and root crops; each equation involving only two explanatory variables, viz., own price to capture short run response and a one-period-lagged output variable to capture long run response. However, a scrutiny of the regression results reveals inadequate empirical evidence for the author’s assertion. This may be attributed to the econometric flaws in the study.

A study by Ramaila et al (2011) did a research on what influences agricultural productivity and supply response. The research found out that productivity analysis and supply response goes much further than just to measure performance and efficiency. The study shows that other factors to be considered include sources of growth, investment in research, improved market access, efficiency gains, technological progress or others.

Chidoko, et.al. (2011) investigated the economic factors affecting the productivity of small scale sugar-cane farmers in the Lowveld of Zimbabwe with particular reference to Chipiwa farmers in Mkwasine area in Chiredzi District. The main objective of the study was to bring to light the economic challenges that contribute towards the low productivity by small scale sugar cane farmers so that the relevant stakeholders can assist to rectify the situation. The research showed that while sugar cane industry is a critical sector to the economy, its productivity is going down. It was discovered that the low productivity is largely due to failure to plough out old cane, lack of equipment for operations, low prices paid for the harvested cane, high transport and haulage charges, limited training and unavailability of inputs. This is largely due to limited access to cheap finance and credit. The research recommends that farmers be given cheap finance and easily access credit using their crop as collateral security.

Branca et al, (2011), researched on a synthesis of empirical evidence of food security and mitigation benefits from improved cropland management food and agriculture. The study found out that, improving cropland management is the key to increasing crop productivity and output without further degrading soil and water resources. At the same time, sustainable agriculture has the potential to deliver co-benefits in the form of reduced GHG emissions and increased carbon sequestration, therefore contributing to climate change mitigation.

Mukuka (2012) examined the supply response of coffee and captured the elasticity response of coffee supply to various incentives in Zambia. The study 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.

The fact that coffee in Zambia is mainly grown for export, the changes in real exchange have the most significant effect on supply in that a depreciation in the Zambian Kwacha leads to an increase in coffee supply.
In addition, the economic reforms which were initiated in Zambia in 1998 have had a positive effect on coffee supply. Overall, coffee supply exhibits threshold adjustments whereby supply tends not to adjust immediately, and does so only when the price shocks in the various incentives (either positive or negative) reach a certain threshold.

Casaburiy et al (2012) did a research on contract farming and agricultural productivity and supply response in Western Kenya. The research found out that in the presence of labor market imperfections that would make plantations inefficient, contract farming can enable producers to take advantage of relevant economies of scale, while preserving the existing allocation of land property rights thereby enhancing production output.

Agwu et al (2012) analyzed the relative effect of climate variability on cassava production in Nigeria. The study recommended mounting of intensive expansion programs to boost cassava production since the crop is not influenced by climate variability as part of efforts to revitalize Nigeria’s export subsector and national income generation drive.

Sibiko (2012) carried out a research study to investigate the determinants of common bean productivity and efficiency of the smallholder farmers in Eastern Uganda. The study findings showed that economic efficiency was positively influenced by value of assets at 1% level and off-farm income and credit at 5% level. However, farmers' primary occupation negatively influenced economic efficiency at 5% level. Allocative efficiency was positively influenced by value of assets at 1% level and farm size and off-farm income at 10% level; while distance to the factor market negatively influenced allocative efficiency at 5% level.

This study recommended the need to increase provision of extension service and training on correct input application and improved farming technologies so as to increase bean productivity. It also suggested the need for policy intervention to discourage land fragmentation, develop road and market infrastructure in rural areas and provide affordable and easily available credit facilities to improve production efficiency of bean farms. The study also found that bean productivity was significantly influenced by plot size, ordinary seeds, and certified seeds and planting fertilizer; all of which had a positive effect as expected.

Asekenye et al (2012) did an analysis of productivity gaps and supply response among smallholder groundnut farmers in Uganda and Kenya. The study found that in Uganda farm yields are lower than the potential yield attainable with adequate farm management. The evidence shows yield gaps of 67% for maize, 78% for groundnut, 67% for sorghum and 40% for egg production earlier evidence revealed that most rice varieties were not achieving their potential yields on farmers' fields in many developing countries (FAO 2004). Yields of 4 to 6 tons per hectare for rice were being obtained compared to a potential of 10 to 11 tons per hectare. Biophysical factors, cultural practices, socio economic conditions, institutional and policy constraints as well as inadequate efforts to transfer technologies and poor market linkages were identified as some of the key reasons for these yield gaps.

A study by German (2013) on Monitoring and Analyzing Food and Agricultural Policies Supply Response along the value chain in selected Sub-Saharan Africa countries found out that price distortions and other non-price factors affected output supply of agricultural products.

Olayiwola (2013) researched on the methodology for supply responses of agricultural crops focusing on how past studies revealed weak supply response for Indian agriculture. This study reviewed methodology adopted by different scholars in the estimation of supply response for both food and non-food crops. The study found out that farmers' response to price change is very low in the short run and their adjustment mechanism towards reaching the desired level is slow for agricultural crops. Various discussions on the supply response theme in the academic literature and in the policy arena clearly pointed out that turning attention to removing some of the physical infrastructural constraints as well as credit constraints will go a long way in increasing the supply response. In conclusion he observed the need for incorporating more variables on weather parameter for long term supply responses looking to climatic changes arising due to global warming.

Retana (2013) researched on the importance of gender parity in relation to productivity supply response. The research showed that societies which promoted gender equality and saw a positive correlation to economic growth, and that gender inequalities did not only result in high human costs but also economic costs by restraining agricultural productivity and supply influence. Based on this study gender equality is, therefore, an integral part of sustainability. This means that if half of society is cut off from opportunities then an operation cannot claim either efficiency or sustainability. Whiles also working to serve the rights and needs of all people, programs and strategies to increase women's leadership at all levels of the coffee production chain have shown to improve benefit sharing within communities, result in better quality coffee and promote company credibility through socially responsible efforts.

Panhuysen et al (2014) investigated the trend of current and future international coffee consumption projections. The study found out that coffee consumption is growing steadily at around 2.5% per year, and the demand for coffee is on the rise. Growth is fastest in the emerging markets, such as those in Eastern Europe and Asia, and in the coffee producing countries themselves. The demand is expected to reach 165 million bags in 2020 and calls for around 15 percent increase in green bean production over the next 5 years. Thereby a shift in demand preference towards Robusta coffee has to be factored in. Global production averages 12 bags per hectare.

They argued that if the production shortfall is to be met by expanding the land under coffee cultivation, it will necessitate opening up at least one million hectares of mostly forest covered land. With the increased pressure on and resources, a more sustainable solution is to produce more coffee per unit of land, water and agrochemicals. The study concluded that to increase and maintain quality and quantity in the long-term, it is of paramount importance to focus on ensuring that women and the next generation of farmers remain in, and benefit from coffee production.

Brando (2014) researched on coffee consumption, production, challenges and opportunities. The study concluded that without higher productivity, future of Arabicas lies on specialty and quality segments while future of Robustas remains difficult to predict.

Kavinya1 et al (2014) carried out a research on maize hectarage response to price and non-price incentives in Malawi and concluded that price incentives are on their own inadequate to influence smallholder farmers' decision to allocate land to maize. This is because farmers are largely constrained by land and cash resources with which to hire labour and to purchase inorganic fertilizer. Therefore, policy needs to go beyond market and price interventions as a means of incentivizing staple food production as non-price incentives are critical in influencing smallholder farmers' production decisions in relation to maize.

Prasanna (2014) carried out a study investigating the issues and challenges faced by tea smallholders in Sri Lanka. He identified weak knowledge of business management and market realities in relation to productivity and supply response being a significant reason that prevents tea smallholders from monitoring their profit or losses. The study demonstrated that there is considerable room to improve the tea small holding sector in Sri Lanka by addressing the existing constraints and revive interest among tea smallholders to expand their cultivable land for tea.

A study done by Njenga (2014) assessed how responsive potato Output was to variable input factors. The study used cross sectional farm level data for the 2011 and 2012 crop years obtained from ninety (90) potato farmers in Kinangop district in Kenya. The study employed Cobb Douglas production function and a profit function to estimate potato output response to variable inputs. Results show that crop farming (potato) was the major source of livelihood; potato production was negatively affected by high input cost, shortage in supply of input, disease, poor selling price, and decrease in market demand. Fertilizer, seeds quality and herbicides cost were factors that affected potato production. The fertilizer costs was the most significant factor, followed by credit access, seed quality and cost, herbicides costs and labour costs respectively.

Ljubljana et al (2014) highlighted important global supply response for key agricultural commodities. The findings revealed that, while higher output prices are incentives to improve global crop supply, output price volatility plays otherwise. Depending on respective crop, the results indicate that own price supply elasticities range from about 0.05 to 0.35. The findings suggest that output price-risk has negative correlations with crop supply, implying that farmers shift land, other inputs and yield improving investments away to crops with less volatile prices. The recent output price volatility seems to significantly reduce production of wheat and to a lesser extent rice

Still, the literature on estimation of supply response to prices has a long history in agricultural economics (Nerlove, 1956). Nevertheless, there are various reasons to reconsider the research on supply response. The majority of the previous empirical literature investigating supply response is concentrated on a few countries. The effect of price and its volatility is usually considered as a microeconomic problem for producers. However, there are several factors such as foreign direct investment in agriculture that make the global and country-level agricultural production equally sensitive to prices and their volatility as is the case at the individual producer level. Another reason for the renewed research interest in the topic is the growing demand for biofuels and the financialization of agricultural commodities, which are suspected to have contributed to the high and volatile food prices that in turn affect the global food supply.

Furthermore existing econometric analyses focus on supply response to domestic prices. This study, on the other hand, investigates the supply response of the key world staples to international market prices. In doing so, the study makes the following major contributions:(i) It provides updated short-and long-term supply elasticities that indicate how major agricultural commodity producers respond to the recent increase in global food prices and volatility. (ii) It provides answers whether the recent increase in prices is an opportunity or a challenge to agricultural producers and to the sector in general. (iii) Given some empirical evidence suggesting that the major proportion of the supply response to output price, in the short-run, is via acreage changes (Roberts and Schlenker, 2009), estimation of both acreage and yield responses to prices is important to contest or affirm this finding.

2.3.3 Research Gap and Conclusion Remarks

The results from earlier studies were not concerned with overall productivity of small holder farming; most of these studies have mainly used time series or cross sectional data separately. However, 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. It is clear for, example, from Njaramba's study (2011) on Kenya's coffee supply response that it covered the entire country's data base and did not focus on coffee smallholdings. It is also noted that none of the cited studies have had a focus in Kiambu's coffee small holder farmers as it has a significant contribution of more than 30% of Kenya's coffee output. Hence, the reaction of Kiambu farmers in varying their coffee output has not been studied by any of the empirical literature given above and makes this research undertaking unique.

Moreover, some of the studies cited have laid emphasis on other agricultural products such as tea, potatoes maize among others and also assessed totally different variables other than those considered for this study. It is on this basis that this research undertaking is totally different from other well-known studies that have been conducted. This research, therefore, bridges the gaps other studies have created. It is clear that this research attempts to address farmers reactions to coffee output as a function of price variations and changes of the cost of the inputs on an annual basis across the three zones individually and all combined as well as over the eleven year production trend period.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter outlines the methodology and procedures applied in conducting the study so as to achieve the purpose of the study. The chapter has been divided into five sections. The first section provides a detailed description of the research design that comprises research area, and study population and sample used. The second section provides a detailed description of the sampling design and methods. The third section focuses on the description of the data generation tools that comprises structured questionnaires, face to face interviews and focused group discussions. The data collection and analysis using Cobb-Douglas production function, and pooled OLS regression model. Finally, in addition to the Cobb-Douglass models presented is section four, this study also examined the supply response of coffee farms by using the Nerlove model; the data analysis procedures for this model are explained in section 3.5.4.

3.2 Research Design

Research design assists in identifying the questions to study, the relevant data, the data collection methods and how to analyze the results. Kombo (2006) defines research design as the scheme, outline or plan that is used to generate answers to research problems. It is an arrangement of conditions of data collection and analysis. The researcher used descriptive survey designed to assess thenature and development of Coffee sector and its problems with a view to offer solutions. It employed the use of interviews and administration of questionnaires to a sample of individual farmers, coffee cooperative societies' officials and Government officials to find out peoples' attitudes, opinion about performance, factors of production that are mainly used, and problems facing coffee sector in Kiambu County. The researcher used both primary and secondary data. Primary data was obtained using questionnaires while secondary data was gathered from the factory documentaries held by farmers, societies and Government.

3.2.1 Descriptive Survey Research Design

A research design is the framework or plan for a study used as a guide in collecting and analyzing data. There are three basic types of research design: exploratory, descriptive, and causal. In this section, we will discuss these types of research design, give some examples, and note when each might be important.

3.2.2 Types of Research Design

There are three types of research design: Exploratory research, Descriptive research and Causal research design.

(a) Exploratory research design: The goal of exploratory research is to discover ideas and insights i.e. the major emphasis is on gaining ideas and insights. To understand a situation better an exploratory research is essential as it forms a basis for formulating hypotheses about what is going on in a situation. A hypothesis is a statement that describes how two or more variables are related. You can't really confirm or reject the hypothesis with exploratory research, though. That job is left for descriptive and/or causal research (these are often called *quantitative research*). Exploratory research does not offer solutions to the problem that is being investigated.

(b) It can never the less enrich information for specific individuals. This is because this research involves a relatively small group of people to participate and who are not randomly chosen.

(c) Descriptive research Design: Descriptive research is usually concerned with describing a population with respect to important variables; the major emphasis is on

(d) Determining the frequency with which something occurs or the extent to which two variables vary. Descriptive research is used:

  (i) To describe the characteristics of certain groups,

  (ii) To determine the proportion of people who behave in a certain way,

  (iii) To make specific predictions,

  (iv) To determine relationships between variables.

Descriptive research can be used to accomplish a wide variety of research objectives. However, descriptive data become useful for solving problems only when the process is guided by one or more specific research problems, much thought and effort, and quite often exploratory research to clarify the problem and develop hypotheses. A descriptive study design is very different from an exploratory study design. Exploratory studies are flexible in nature; descriptive studies are not. They require a clear specification of the: who, what, when, where, why, and how of the research.

Causal research Design**:** Causal research is used to establish cause-and-effect relationships between variables; the major emphasis is on determining the cause-and-effect relationships. Experiments are commonly used in causal research designs because they are best suited to determine cause and effect.

3.3 Sampling Design and Methods

Sampling Design and Methods: Sampling was computed according to the formula developed by Nassiuma (2000) given as:

$$n = \frac{Nc^2}{c^2 + (N-1)e^2} \qquad 3.1$$

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, 32 from upper midland zone 3 were interviewed out of a total population of about

220,000 small scale coffee farmers in Kiambu County. 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.

3.4 Data Generation Tools

It is to be noted that the most appropriate instrument that was used to collect data from individual farmers and other stakeholders was a well-designed questionnaire. In carrying out the study so as to prove the research questions mentioned above 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. Prevailing prices were also obtained from the various coffee societies to determine how their variations could influence the supply response of coffee outputs

3.5 Data Collection and Analysis

A desk review was carried out from the following sources:

(i) Existing materials on coffee and coffee production in Kenya and other countries,

(ii) 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).

The time series data was collected at National level for a period of ten years to ascertain the trend of coffee production in Kenya. A structured questionnaire was used to collect data from individual farmers. Face to face interviews were also carried out to the individual farmers and some Government officials. Data collected was analyzed by applying the Cobb-Douglas production function, and by the use of the SPSS/STATA Statistical packages for the final research report. Data collected was, among other things, used:

(a) To assess the contribution of all three factors, namely farm size, quantity of fertilizer used and quantity of spray chemicals used in a given year of production using Cobb-Douglas production function

(b) To assess the individual contribution of each of the above three factors using the pooled OLS regression model.

(c) To determine which of the three factors of production has the highest contribution to coffee productivity.

(d) To estimate and analyze short run and long run supply response of coffee production by using Nerlove model.

(e) To investigate and determine the coffee production trend for the last ten years in Kiambu County.

In this research both the Cobb-Douglas production function together with the pooled OLS regression model were used to determine the contribution of the various factors of production to the coffee productivity in Kenya.

The data collection process was based on the stated sample sizes cited above as coverage of the entire population would be costly and time consuming. The final data was then analyzed by use of the STATA Statistical packages for the final research report. Care was exercised to get adequate sample size in all the areas and covering both the small holdings and the large farms so that in the final analysis results could be used to depict a true picture of what goes on in this sub-sector as far as productivity levels are concerned by the use of the various factors of production.

3.5.1 Cobb- Douglas Production Function

Data collected was, among other things, used to assess the individual contribution of each factor to coffee productivity. This entailed applying a multi-factor productivity approach by the use of the **Cobb-Douglas production function**. The Cobb-Douglas functional form of production is widely used to represent the relationship of an output to inputs. In 1928, Charles Cobb and Paul Douglas published a study in which they modeled the growth of the American economy during the period 1899-1922.

They considered a simplified view of the economy in which production output is determined by the amount of labour involved and the amount of capital invested. While there are many other factors affecting economic performance, their model proved to be remarkably accurate. The function they used to model production was of the form:

$$P(L,K) = bL^{\alpha}K^{\beta} \qquad 3.2$$

Where:

P = Total output per annum

L = Labour input per annum

K = Capital input

b = multi-factor productivity

α = output elasticities of labour

β = output elasticities of capital

α and β are constants values determined by the existing technologies.

This model is therefore useful in determining how coffee output in Kenya is influenced by various other inputs or factors of production that include farm sizes in hectares, quantity of fertilizers and spray chemicals used in a year. Hence, the Cobb-Douglas production function can be re-written in an extended form as follows:

$$P(X_1, X_2, X_3) = aX_1^{b_1} X_2^{b_2} X_3^{b_3} e^{\mu t} \qquad 3.3$$

Where P is the Coffee output,

a = total factor productivity

X_1 = Coffee farm sizes in hectares

X_2= Quantity of Fertilizers used in a year

X_3 = Quantity of spray chemicals used in a year.

The values given as b_1, b_2, b_3 and ut 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:

$$LnP = lnA + b_1 lnX_1 + b_2 lnX_2 + b_3 lnX_3 + \mu t \qquad 3.4$$

By getting appropriate data and fitting in into the system, it is then possible to run an econometric estimation by using either STATA to get the values of the output elasticities stated above. This would then be used to ascertain whether the production technology involved is exhibiting any of the following three features:

If $b_1 + b_2 + b_3 = 1$, then the production technology would be exhibiting constant returns to scale, meaning that doubling of inputs will double output. If $b_1 + b_2 + b_3 < 1$, then the production technology would be exhibiting 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 would be exhibiting increasing returns to scale, meaning that doubling of inputs will more than double the output.

3.5.2 Specifications of the Panel Data Models

The basic framework for this discussion is a regression model of the form:

$$Y_{it} = X'_{it}\beta + Z'_i\alpha + \varepsilon_{it} \qquad 3.5$$

There are *K* regressors in X_{it}, excluding a constant term. The heterogeneity, or individual effect is $Z_i\alpha$ where Z_i contains a constant term and a set of individual or group specific variables, which may be observed, or unobserved. The set of individual or group specific variables are taken to be constant over time *t*. If Z_i is observed for all individual coffee farmers, then the entire model can be treated as an ordinary linear model and can be estimated using the Ordinary Least Squares (OLS) technique.

3.5.2.1 Pooled Regression

From the equation, $Y_{it} = X'_{it}\beta + Z'_i\alpha + \varepsilon_{it}$. If Z_i contains only a constant term, then ordinary least squares provides consistent and efficient estimates of the common α and the slope vector $\boldsymbol{\beta}$.

3.5.2.2 Fixed Effects

Also, from the equation, $Y_{it} = X_{it}'\beta + Z_i'\alpha + \varepsilon_{it}$. If Z_i is unobserved, but correlated with X_{it} then the least squares estimator of $\boldsymbol{\beta}$ is biased and inconsistent. However, in this instance, the model

$$Y_{it} = X_{it}'\beta + \alpha_i + \varepsilon_{it} \quad 3.6$$

where $\alpha_i = Z_i\alpha$, embodies all the observable effects and specifies an estimable conditional mean. This fixed effects approach takes α_i to be a group-specific constant term in the regression model. It should be noted that the term "fixed" as used here indicates that the term does not vary over time, not that it is non-stochastic, which need not be the case.

3.5.2.3 Random Effects

If the unobserved individual heterogeneity, however formulated, can be assumed to be uncorrelated with the included variables, then the model may be formulated as:

$$Y_{it} = X_{it}'\beta + \alpha + \mu_i + \varepsilon_{it} \quad 3.7$$

that is, as a linear regression model with a compound disturbance that may be consistently, albeit inefficiently, estimated by least squares. This random effects approach specifies that μ_i is a group specific random element, similar to ε_{it} except that for each group, there is but a single draw that enters the regression identically in each period. The crucial distinction between these two cases is whether the unobserved individual effect embodies elements that are correlated with the regressors in the model, not whether these effects are stochastic or not.

3.5.3 Panel Data Regression Model with Dummy Variables

To determine the optimal combination of the factors of production for higher coffee productivity this study used panel data regression model, which incorporated dummy variables as regressors to ascertain the contribution of each factor of production as we hold other factors constant. Specifically the pooled OLS regression model was utilized.

3.5.4 Nerlove Model

In addition to the Cobb-Douglass models presented above, this study also examined the supply response of coffee farms by using the Nerlove model. In its simplest version Nerlove's model consists of the three equations:

$$A_{it}^{*} = \alpha_0 + \alpha_1 P_{it}^{*} + \mu it \qquad 3.8$$

$$A_{it}^{*} = P_{i(t-1)}^{*} + \beta(P_{i(t-1)} - P_{i(t-1)}^{*}) \qquad 3.9$$

$$A_{it} = A_{i(t-1)} + \gamma(A_{it}^{*} - A_{i(t-1)}) \qquad 3.10$$

Where ***A**$_t$* and ***A**$_t$** are actual and desired area under cultivation (or sometimes output or yield) at time ***t***, ***P**$_t$* and ***P**$_t$** 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

$$A_{it} = b_0 + b_{1it} P_{i(t-1)} + b_{2it} A_{i(t-1)} + b_{3it} A_{i(t-2)} + \nu it \qquad 3.11$$

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

$$\nu_{it} = \gamma(\mu_{it} - (1-\beta)\mu_{i(t-1)}\alpha \qquad 3.12$$

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

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

$$\varepsilon = \alpha_1 \frac{\bar{P}}{\bar{A}} = \frac{b1it}{1 - b2it - b3it} \frac{\bar{P}}{\bar{A}} \qquad 3.13$$

Where $\bar{\rho}$ and $\bar{A}$, could represent some historical mean of prices and acreage under cultivation, respectively. Much as we acknowledge that Nerlove model (which is normally used for annual crops) is too old, I looked at recent literature that attempted to modify it, and then I adapted it for coffee which is a perennial crop and to the Kiambu environment. Alternatively, in the case of uprooted crops the use of Polynomial Distributed Lag formulation Model of price expectations which allows the weights assigned to past prices to first increase and then decrease can be applied (Nakabo, 1992). However, in the case abandonment Nerlove Model will still be relevant. A review of Nerlove's supply response model indicates that the main objection to using his model to explain the supply of perennial crops such as coffee is that it is based upon a set of *ad hoc* behavioural relationships. Therefore the derived supply function fails to capture adequately the distributed lag response of coffee supply to past investment (Gatete, 1993). A preferable method to estimate the supply response is to directly estimate the individual structural relationships underlying the supply of coffee. These are the investment function, the harvesting decision and the vintage production function.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the findings of the study based on different study objectives. It starts by giving the results of diagnostic tests conducted then presents the study findings as per the objectives.

The objectives of the study were to 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 Function of Production; to investigate and determine the individual contribution to coffee productivity by farm size, type of fertilizer used and the type of chemical spray used; to estimate and analyze short run and long run supply response of coffee production by using Nerlove model; and to investigate and determine the coffee production trend for the last ten years in Kiambu County.

4.2 Characteristics of the Coffee Farmers Interviewed

The descriptive statistics generated from the study showed that a total of 1,375 coffee farmers were interviewed. Of these, 517 (37.6%) were drawn from UM1 zone, 506 (36.8%) were from UM2 zone while the remaining 352 (25.6%) were from UM3 zone as illustrated in Table 4.1.

The summary statistics given in Table 4.1 indicates that a total of 449 coffee farmers or 32.65 per cent of the farmers interviewed never used fertilizer in coffee production. However, 790 or 57.45 per cent of the farmers used compound fertilizer while 485 or 35.27 per cent of the farmers used CAN fertilizer. Similarly a total of 731 Coffee farmers or 53.16% of the farmers never used spray chemicals at all. However, 43.55% and 27.5% of the farmers used copper spray and sumithon respectively.

A disaggregation of the respondents by level of education shows that 60 or 4.36 per cent of the coffee farmers interviewed had no education at all. Moreover, 414 or 30.11 per cent of the coffee farmers interviewed had attained primary level of education while 674 or 49.02 per cent of the coffee farmers had secondary level of education. Further, 227 or 16.51 per cent of the coffee farmers interviewed had attained post-secondary level of education.

Table 4.1: Characteristics of the Coffee Farmers by Zones

	UM1		**UM2**		**UM3**		**Total**	
	Frequency	**%**	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**
Type of Fertilizer Used								
No Fertilizer Used	206	14.98	169	12.29	74	5.38	449	32.65
Compound Fertilizer Used	267	19.49	290	20.87	233	17.09	790	57.45
CAN Fertilizer Used	141	10.25	197	14.25	147	10.76	485	35.27
Type of Spray Used								
No Spray Used	332	24.15	216	15.71	183	13.31	731	53.16
Copper Spray Used	174	12.87	264	18.98	158	11.49	596	43.35
Sumithion Spray Used	105	8.00	166	11.85	110	7.85	381	27.71
Level of Education								
No Education	15	1.09	33	2.40	12	0.87	60	4.36
Primary Education	207	15.05	112	8.15	95	6.91	414	30.11
Secondary Education	213	15.49	278	20.22	183	13.31	674	49.02
Post-Secondary Education	82	5.96	83	6.04	62	4.51	227	16.51
Total	**517**	**37.60**	**506**	**36.80**	**352**	**25.60**	**1375**	**100.00**

Source: Field Data (2016)

Tables 4.2, 4.3 and 4.4 give the farm and output characteristics for the coffee farmers in zones UM1, UM2 and UM3 while Table 4.5 gives the farm and output indicators for the combined zone. The descriptive statistics presented in Table 4.2 shows that coffee farmers in UM1 zone had an average farm size of 1.529 acres. The minimum farm size was 0.2 acres while the maximum was 5 acres.

Table 4.2: Descriptive Statistics for UM1 Zone

UM1 Zone				
Variable	**Observation**	**Mean**	**Minimum**	**Maximum**
Farm size in acres	517	1.529	0.2	5
Coffee output in Kgs	517	632.271	50	5800
Coffee price per Kg in Kshs	517	36.252	10.15	78.2
Quantity of Compound fertilizer used	267	137.023	10	700
Quantity of CAN fertilizer used	141	180.106	20	700
Quantity of copper spray used	174	2.772	1	9
Quantity of sumithion spray used	105	3.451	1.2	9

Source: Field Data (2016)

According to the statistics presented in Table 4.2, the average coffee output produced by the farmers in the zone was 632.271 Kgs. According to the data, the minimum output recorded by an individual farmer was 50 Kgs while the maximum output was 5800 Kgs. Similarly, the coffee price per Kg in the zone averaged Kshs 36.25; the price variation between farmers and time period was, however, high with the least price attained being Kshs 10.15 and the maximum was Kshs 78.20.

Table 4.2 also shows that the quantity of triple 17 (compound) type of fertilizer used by the coffee farmers in UM1 zone was on average 137.023Kgs. This is compared to an average of 180.106Kgs of calcium ammonium nitrate (CAN) type of fertilizer used by the farmers in the zone. The minimum quantity of CAN fertilizer used was

20Kgs and the maximum was 700Kgs. This shows that on average the coffee farmers in UM1 zone used more of CAN fertilizer compared to compound fertilizer. Table 4.2 further shows that the coffee farmers in UM1 zone used on average 2.772 litres of copper spray and 3.451 litres of sumithion type of spray. Furthermore, the minimum quantity of copper and sumithion types of spray used were 1litre and 1.2litres respectively, and similarly, the maximum quantity of spray used was 9 litres for copper and an equal quantity of 9litres for sumithion type of spray.

Table 4.3 gives a summary of farm and production indicators for UM2 zone. The summary indicators provided show that that the coffee farmers in the zone had an average farm size of 2.507 acres. As in the case of the farmers in UM1 zone, those in UM2 zone had a minimum farm size of 0.2 acres but a much larger farm size of 20 acres at the maximum point.

Table 4.3: Descriptive Statistics for UM2 Zone

UM2 Zone				
Variable	**Observation**	**Mean**	**Minimum**	**Maximum**
Farm size in acres	506	2.507	0.2	20
Coffee output in Kgs	506	1641.955	0	12500
Coffee price per Kg in Kshs	506	29.867	6.7	67.9
Quantity of Compound fertilizer used	290	170.983	10	700
Quantity of CAN fertilizer used	197	184.452	8	650
Quantity of copper spray used	264	4.616	1	30
Quantity of sumithion spray used	166	6.346	0.2	30

Source: Field Data (2016)

According to the data presented in Table 4.3, the average coffee output produced by the farmers was 1641.955 Kgs. Similarly, the coffee price per Kg was on average

Kshs 29.87 with the least being Kshs 6.70 and the maximum was Kshs 67.90. As illustrated in Table 4.3, the mean quantity of triple 17 (compound) type of fertilizer used by the coffee farmers in UM2 zone was170.983Kgs. The farmers also used an average of 184.452Kgs of CAN type of fertilizer. The minimum quantity of CAN fertilizer used was 8Kgs and the maximum was 650Kgs. This shows that on average, the coffee farmers in UM2 zone used more of CAN fertilizer compared to compound fertilizer. Table 4.3 also shows that the coffee farmers in UM2 zone used on average 4.616 litres of copper spray and 6.346 litres of sumithion type of spray.

In the case of the farmers in UM3 zone (see Table 4.4), the mean farm size was 1.608 acres with the minimum farm size being 0.25 acres and the maximum 10 acres. The average coffee output produced by the farmers was 1257.926kgs.

Table 4.4: Descriptive Statistics for UM3 Zone

UM3 Zone				
Variable	**Observation**	**Mean**	**Minimum**	**Maximum**
Farm size in acres	352	1.608	0.25	10
Coffee output in Kgs	352	1257.926	0	50000
Coffee price per Kg in Kshs	352	34.185	8.2	73.9
Quantity of Compound fertilizer used	233	158.906	25	700
Quantity of CAN fertilizer used	147	203.197	50	700
Quantity of copper spray used	158	6.437	1	30
Quantity of sumithion spray used	110	8.266	0.3	30

Source: Field Data (2016)

As presented in Table 4.4, the mean price fetched by the farmers in the zone from the coffee sales was Kshs 34.19. The lowest price that was ever realized by the farmers was Kshs 8.20 per Kg while the maximum was Kshs 73.90 per Kg.

Table 4.4 also shows that the quantity of triple 17 (compound) type of fertilizer used by the coffee farmers in UM3 zone was on average 158.906Kgs. However, the coffee farmers in the zone used an average of 203.197Kgs of CAN type of fertilizer with the minimum quantity of the fertilizer used being 50Kgs and the maximum being 700Kgs. This shows that on average the coffee farmers in UM3 zone used more of CAN fertilizer compared to compound fertilizer. Table 4.4 further shows that the coffee farmers in UM3 zone used on average 6.437litres of copper spray and 8.266litres of sumithion type of spray. The minimum quantity of copper and sumithion types of spray used was 1 litre and 0.3 litres, respectively. Similarly, the maximum quantity of spray and sumithion type of spray used by the farmers was equal at 30 litres. Table 4.5 gives similar summary farm and production statistics for all the zones.

Table 4.5: Descriptive Statistics for All Zones Combined

All Zones				
Variable	**Observation**	**Mean**	**Minimum**	**Maximum**
Farm size in acres	1375	1.909	0.2	20
Coffee output in Kgs	1375	1164.002	0	50000
Coffee price per Kg in Kshs	1375	33.373	6.7	78.2
Quantity of Compound fertilizer used	790	155.943	10	700
Quantity of CAN fertilizer used	485	188.870	8	700
Quantity of copper spray used	596	4.560	1	30
Quantity of sumithion spray used	381	6.103	0.2	30

Source: Field Data (2016)

The data presented in Table 4.5 indicates that the mean farm size for the combined zones was 1.909 acres with the minimum farm size being 0.2 acres and the maximum 20 acres. The average coffee output produced by the farmers was 1164.002 Kgs, which fetched a mean price of Kshs 33.37 per Kg. The minimum price realized by the farmers was Kshs 6.70 per Kg. and the maximum was Kshs 78.20 per Kg.

Table 4.5 also shows that the quantity of triple 17 (compound) type of fertilizer used by the coffee farmers in all the zones was on average 155.943Kgs. As illustrated in Table 4.5, the coffee farmers in all the zones used an average of 188.870Kgs of CAN fertilizer. The minimum quantity of CAN fertilizer used by the farmers was 8Kgs and the maximum was 700Kgs. This shows that on average the coffee farmers in all the zones used more of CAN fertilizer compared to compound fertilizer. Table 4.5 further shows that the coffee farmers in all the zones used on average 4.560 litres of copper spray and 6.103 litres of sumithion type of spray.

4.3 Diagnostic Test Results

Before estimating the different functions to address the study objectives, the researcher first conducted a panel unit root test 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 Im- Pesaran-Test (IPS) was not used since the panel was a balanced one and IPS is best applied for unbalanced panel data. The three tests (LLC, HT and Breitung) were done at levels, at first difference and at levels with time trend included. Table 4.6 gives the summary of the unit root test based on the Breitung Test.

Another model that is normally used for partial factor contribution of productivity is stochastic frontier production function; however this model doesn’t give appropriate results on balanced panel data.

Table 4.6: 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*

* denotes statistical significance at the 5 percent level

In the test results presented in Table 4.6, the lambda statistic and the associated p-value for the variables at level show 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.

The researcher further conducted a test for multicollinearity using the variance inflation factor (VIF) and the results are presented in Table 4.7. Year 2004 and zone UM1 have been used as control variables.

The results presented in Table 4.7 show that the mean VIF was estimated at 2.55, which is greater than the critical value of 1. As indicated in Table 4.7, no VIFs was greater than 10. This demonstrates absence of strong multicollinearity.

Table 4.7: Variance Inflation Factor Test for Multicollinearity

Variable	**VIF**	**1/VIF**
Ln farm size in acres	1.21	0.8251
Ln quantity of 17 17 17 type of fertilizer	1.16	0.8625
Ln quantity of CAN type of fertilizer	1.19	0.8431
Ln quantity of copper type of spray	4.1	0.2436
Ln quantity of sumithion type of spray	3.85	0.2599
Primary education	5.93	0.1686
Secondary education	7.38	0.1356
Post secondary education	4.99	0.2004
Year 2005	1.84	0.5430
Year 2006	**1.76**	0.5670
Year 2007	1.79	0.5589
Year 2008	1.74	0.5744
Year 2009	1.82	0.5487
Year 2010	1.77	0.5637
Year 2011	1.82	0.5491
Year 2012	1.84	0.5434
Year 2013	1.87	0.5358
Year 2014	1.78	0.5618
UM2 zone	1.48	0.6768
UM3 Zone	1.61	0.6215
Mean VIF	**2.55**	

Source: Field Data (2016)

4.4 Area under Coffee Production and Its Productivity

Table 4.8 shows the area under coffee production and its productivity in the period between 2004 and 2014, with small holdings in UM1 zone in Kiambu County. This is an Upper Mid land zone mainly suitable for both Coffee and Tea Growing. The area under coffee did not change much as it remained constant at 28 hectares except in 2005 and 2009 when it was 30 Hectares and 27 Hectares respectively. The Coffee Output varied modestly in the same period with highest yields of 10701 kg realized in 2004 and lowest yields of 6524 kg realized in 2014. The productivity ranged between 233.8 kg/Ha to 369.2 Kg/ Ha realized in 2014 and 2004 respectively. It is clear that productivity here was much higher compared with productivity of coffee from small holdings at the national level. However, the productivity is lower than that of the coffee estates assessed at the National level.

Table 4.8: Area under Coffee Production and its Productivity in UM1 Zone

No	Year	Farm size (Ha)	Coffee Output (KG)	Productivity
1	2004	28.9	10701	369.2
2	2005	30.3	8880	296.5
3	2006	28.4	8904	318.0
4	2007	28.8	7420	265.1
5	2008	28.8	7140	255.9
6	2009	27.4	6534	242.3
7	2010	28.8	7392	264.2
8	2011	28.8	7756	277.0
9	2012	28.8	7616	272.5
10	2013	28.2	6844	248.0
11	2014	28.6	6524	233.8

Source: Field Data (2016)

Figure 4.1 gives a schematic illustration of the trends in coffee production and coffee productivity in the UM1 zone over the period 2004 to 2014. The illustrations presented in Figure 4.1 indicate a general decline in coffee production between 2004 and 2009, a short recovery period in 2010/2011, and a further decline in 2012 to 2014. Coffee productivity has remained generally subdued.

Table 4.9 shows area under coffee production and its productivity in the period between 2004 and 2014, with small holdings in UM2 zone in Kiambu County. This is an Upper Mid land zone suitable mainly for growing Coffee. Figure 4.2 also gives an illustration of the coffee output and coffee productivity in the zone.

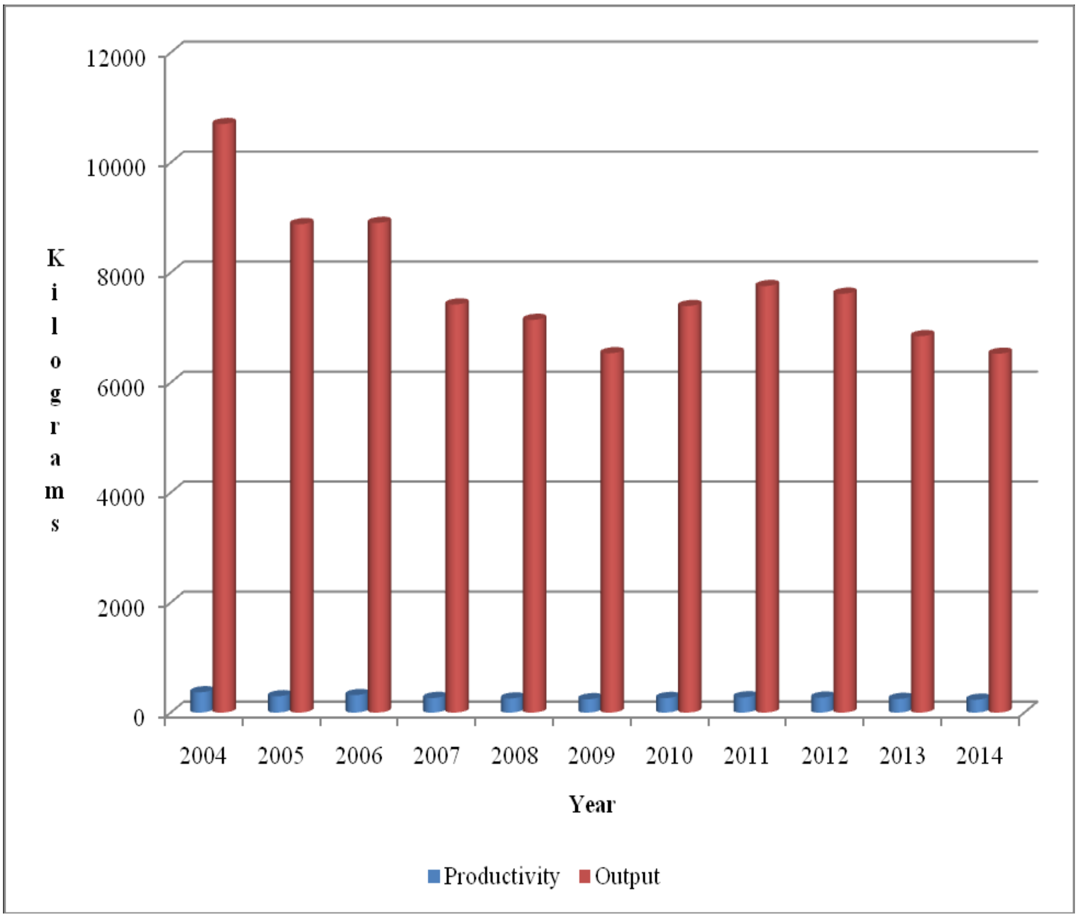

Figure 4.1: Coffee Production and Productivity in UM1 Zone

Source: Field Data (2016)

Table 4.9: Area under Coffee Production and its Productivity in UM2 Zone

No	Year	Hectarage	Coffee Output (KG)	Productivity
1	2004	45.4	16,742.1	368.8
2	2005	45.4	18,707.0	412.0
3	2006	45.0	18,352.4	407.8
4	2007	45.8	16,979.9	370.7
5	2008	45.8	18,430.1	402.4
6	2009	48.3	16,286.6	337.2
7	2010	45.8	15,594.5	340.5
8	2011	45.8	18,445.3	402.7
9	2012	45.8	20,033.1	437.4
10	2013	45.8	22,041.7	481.3
11	2014	48.5	19,387.4	399.7

Source: Field Data (2016)

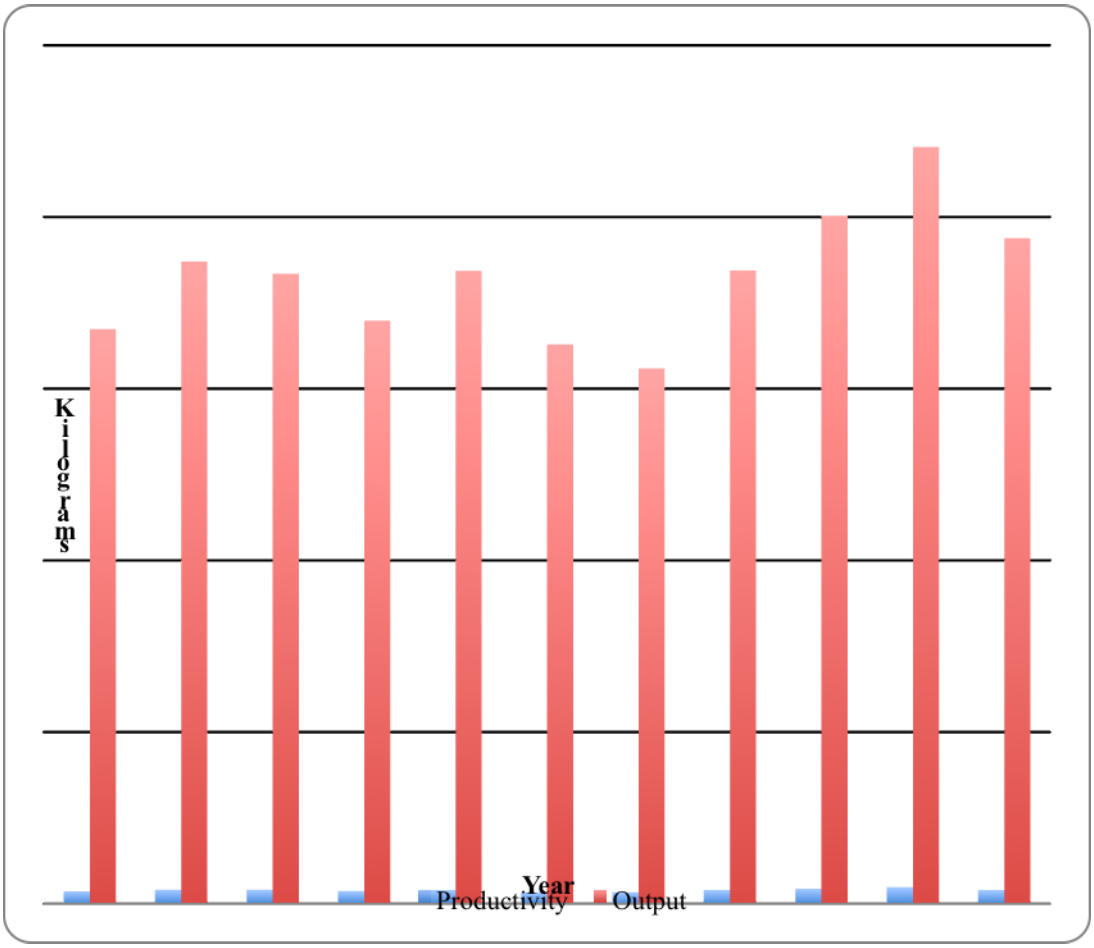

Figure 4.2: Coffee Production and Productivity in UM2 Zone
Source: Field Data (2016)

The data provided in Table 4.9 shows that the area under coffee remained nearly constant throughout at 45 Hectares other than the year 2014 when it increased to 48 Hectares. The coffee output was almost twice that realized in UM1. As illustrated in both Table 4.9 and Figure 4.2, the coffee productivity was cyclical over the period.

Table 4.10 shows area under coffee production and its productivity in the period between 2004 and 2014, with small holdings in UM3 zone in Kiambu County. This is an Upper Mid land zone suitable for growing Coffee and other subsistence crops such as maize, beans and potatoes among others.

Table 4.10: Area under Coffee Production and its Productivity in UM3 Zone

No	Year	Farm Size (Ha)	Coffee Output (KG)	Productivity
1	2004	20.0	7,360.6	368.0
2	2005	20.5	8,101.6	395.2
3	2006	20.4	7,795.4	382.1
4	2007	20.3	11,232.9	553.3
5	2008	20.3	8,358.0	411.7
6	2009	20.2	9,216.4	456.3
7	2010	20.2	8,544.4	423.0
8	2011	20.1	8,510.4	423.4
9	2012	20.1	13,330.4	663.2
10	2013	20.1	11,924.2	593.2
11	2014	24.1	10,441.1	433.2

Source: Field Data (2016)

The data presented in Table 4.10 shows that the area under coffee remained nearly constant throughout at 20 Hectares except for 2014 when acreage increased modestly to 24 Hectares. It may be deduced from Table 4.10 that the area under coffee in UM3 zone was nearly half that of UM2 zone. Figure 4.3 gives a graphical illustration of the coffee output and coffee productivity in UM3 zone over the period 2004 to 2014.

The illustrations presented in Figure 4.3 shows that coffee production in UM3 zone remained almost constant in most of the years. Peaks in coffee production were only realized in 2007, and 2012-2014 in the 11-year period of the analysis. As illustrated in Figure 4.3, coffee productivity also remained almost the same except in 2012 and 2013 when it was at its peak.

Table 4.11 shows the area under coffee production, coffee output and coffee productivity in the period between 2004 and 2014 in all the three zones in Kiambu County.

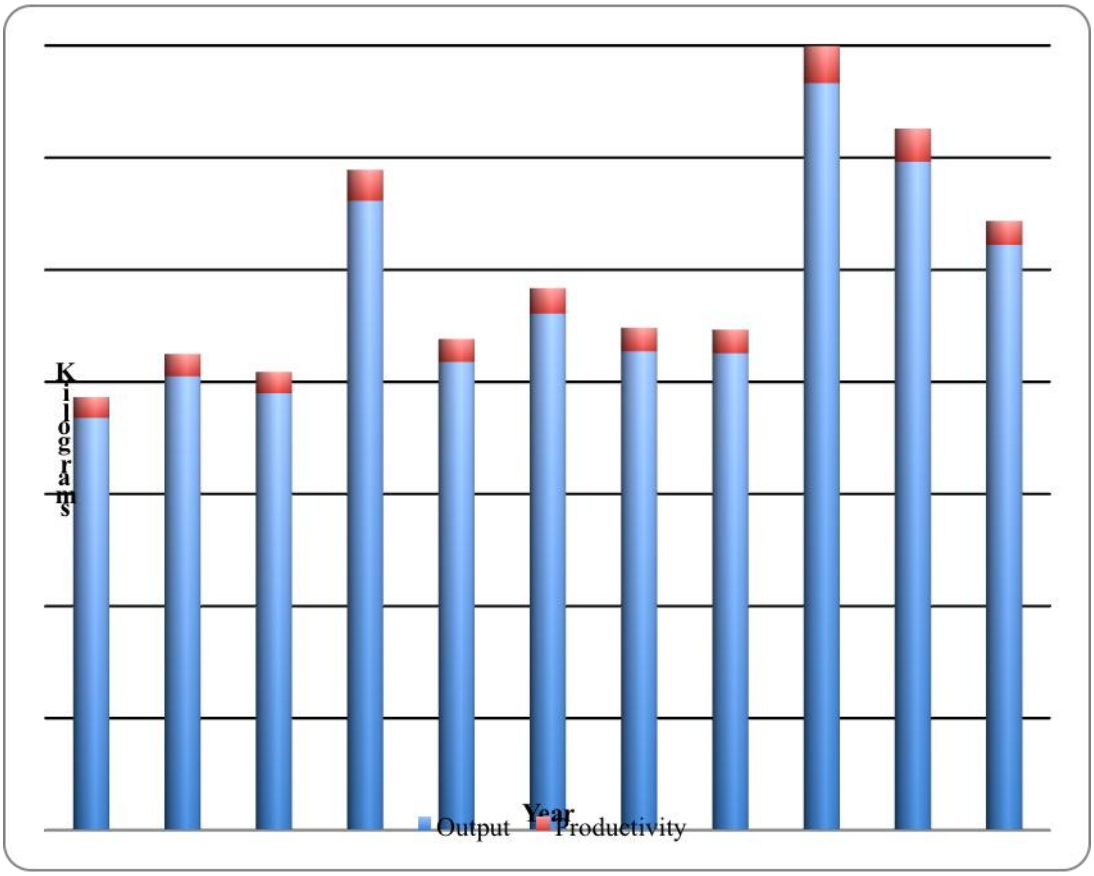

Figure 4.3: Coffee Production and Productivity in UM3 Zone
Source: Field Data (2016)

Table 4.11: Area under Coffee Production and its Productivity in the Three Zone

No	Year	Farm Size (Ha)	Coffee Output (KG)	Productivity
1	2004	94.4	34,805.3	368.7
2	2005	96.3	35,428.8	367.9
3	2006	93.8	34,640.3	369.3
4	2007	95.0	37,658.0	396.4
5	2008	95.0	33,886.5	356.7
6	2009	96.0	33,139.2	345.2
7	2010	95.0	32,547.0	342.6
8	2011	95.0	34,931.5	367.7
9	2012	95.0	43,481.5	457.7
10	2013	95.0	41,876.0	440.8
11	2014	101.2	35,986.7	355.6

Source: Field Data (2016)

The data presented in Table 4.11 shows that the area under coffee varied slightly from 93.8 hectares in 2006 to 101 Hectares in 2014. Coffee output ranged between 32,547 Kg in 2010 and 43,481.5 Kg in 2012. Similarly, coffee productivity ranged between 342.6 Kg/ha in 2010 and 457.7 kg/ha in 2012. Figure 4.4 gives a schematic illustration of the trends in coffee output and coffee productivity in all the combined zones over the period 2004 to 2014.

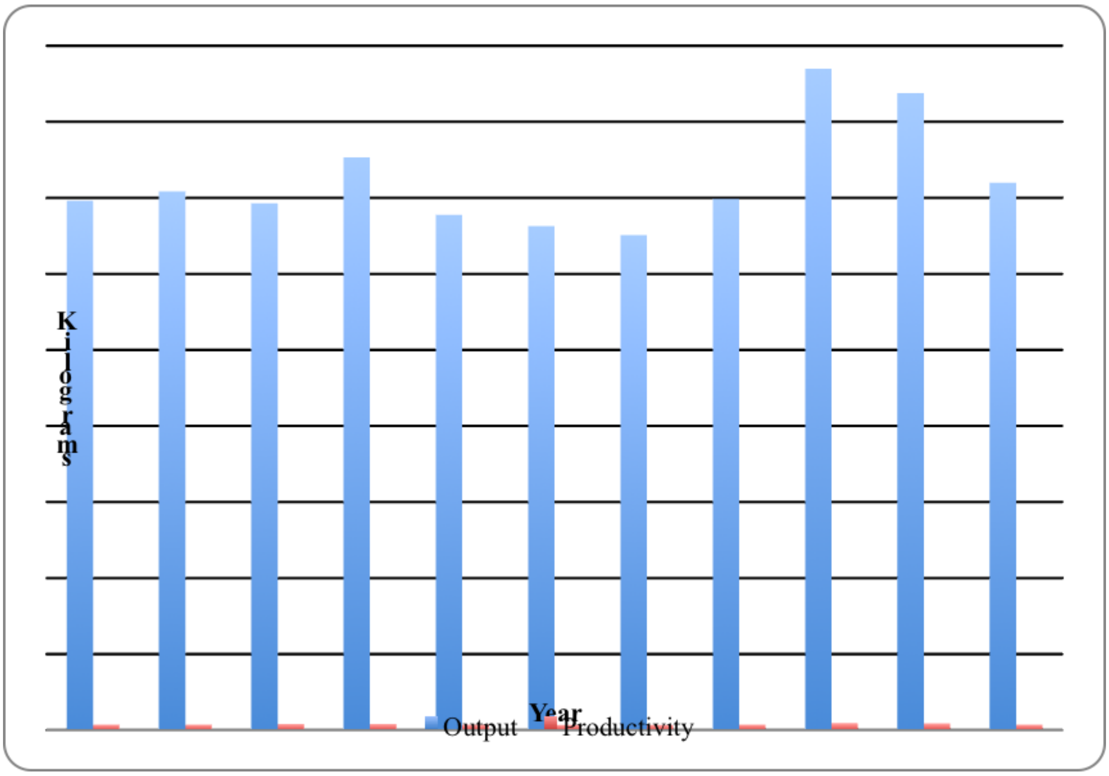

Figure 4.4: Coffee Production and Productivity in Combined Zone
Source: Field Data (2016)

The data presented in Figure 4.4 shows that coffee production was generally cyclical over the period of the analysis. As was the case under UM3, coffee production in the combined zones remained almost constant in most of the years with peaks recorded in 2007, and 2012-2014. Coffee productivity also remained almost the same except in 2012 and 2013 when it was above the 400Kg/ha mark.

Figure 4.5 gives a schematic illustration of the comparative analysis of coffee productivity in Kiambu County in terms of the respective zones and for all the zones combined.

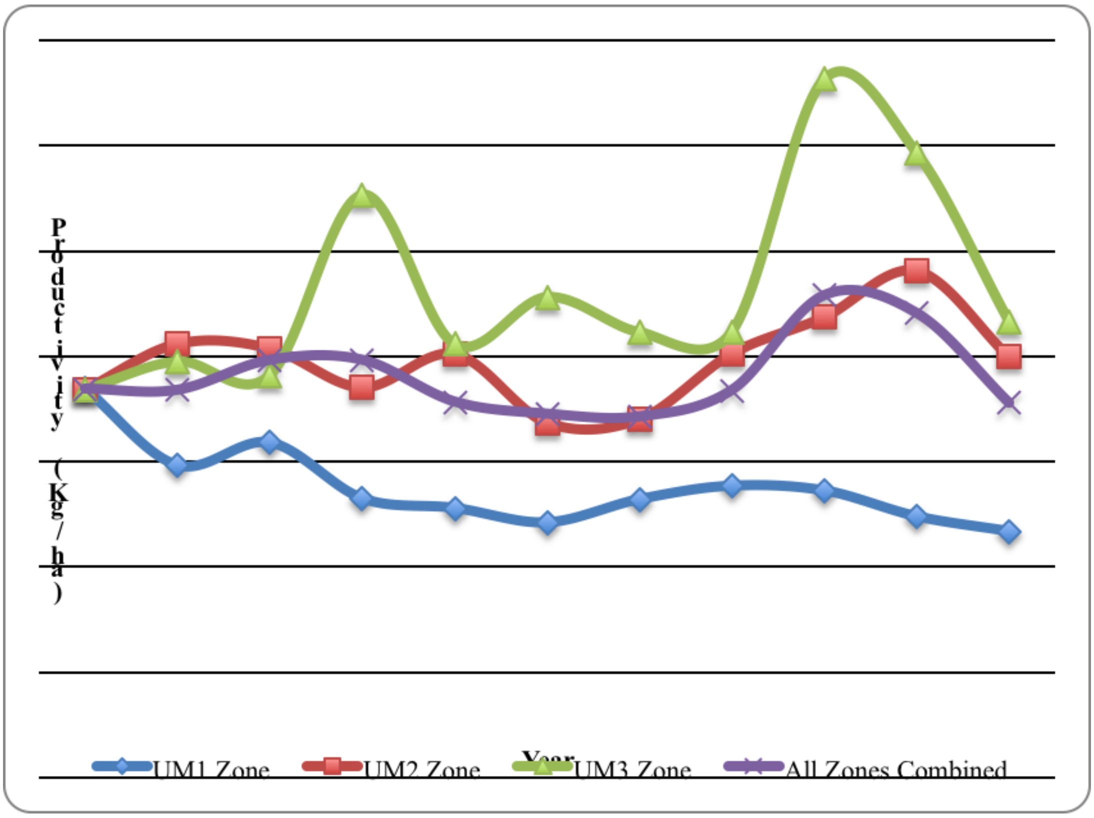

Figure 4.5: Comparative Analysis of Coffee Productivity in Kiambu County
Source: Field Data (2016)

The illustrations in Figure 4.5 show that coffee productivity in Kiambu County has been generally cyclical, and declining for most of the years. According to the data presented in Figure 4.5, coffee productivity in UM1 zone has been generally subdued with gradual decline. However, though productivity in UM3 zone has been higher than that of other zones, it has had the greatest variation. Table 4.12 shows that most farmers in all the three zones would prefer to lease out their farms than grow coffee. This means that the farmers consider leasing out of farms to be more beneficial.

Table 4.12(a): Leasing out versus Growing Coffee in all the Three Zones

Admin Zone Pearson chi2(2) = 7.68 Pr = 0.021		**Lease or grow coffee**		**Total**
		Grow Coffee	**Lease**	
	UM1	236	281	517
	UM2	243	263	506
	UM3	136	216	352
Total		**615**	**760**	**1375**

Source: Field Data (2016)

Tables 4.12b shows that most educated farmers would prefer to lease out their farms than grow coffee in all the three zones.

Table 4.12(b): Leasing out versus Growing Coffee in all the Three Zones, and Education Level

Education level	Lease or grow coffee		Total
	Grow Coffee	Lease	
College	116	111	227
Secondary	298	376	674
Primary	201	273	474
Total	**615**	**760**	**1375**

Source: Field Data (2016)

4.5 Rationalizing the Choice of Model

The data used in this study is panel data. There are two types of models used in carrying out regression analysis with panel data: fixed effects and random effects models. 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.

Statistically, 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 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. 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 estimators, so one should run random effects if it is statistically justifiable to do so.

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 Table 4.13.

Table 4.13: Test for Choosing between Fixed Effects and Random Effects Models

	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 (0.3819) 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.

4.6 Cobb-Douglas Production Functions

The Cobb-Douglas function of production functions is widely used to represent the relationship of an output to inputs. The general function used to model production is of the form:

$$(L, K) = \alpha L^{\alpha} K^{\beta} \qquad 4.1$$

Where:

P = total production (the monetary value of all goods produced in a year)

L = labor input (the total number of person-hours worked in a year)

K = capital input (the monetary worth of all machinery, equipment, and buildings)

a = total factor productivity

α and β are the output elasticities of labor and capital, respectively. These values are constants determined by available technology.

Output elasticity measures the responsiveness of output to a change in levels of either labor or capital used in production. Further, if $\alpha + \beta = 1$, the production function has constant returns to scale. That is, if L and K are each increased by 20%, then P increases by 20%. If $\alpha + \beta < 1$, then the production function exhibits decreasing returns to scale. That is, if L and K are each increased by 20%, then P increases by less than 20%. %. If $\alpha + \beta > 1$, then the production function exhibits increasing returns to scale. That is, if L and K are each increased by 20%, then P increases by more than 20%.

In this study, various forms of the Cobb-Douglas function of production were used. The first one was of the form;

$$P(L, A, K) = bA^{\mu}L^{\alpha}K^{\beta} \quad 4.2$$

Where:

P = total production (the monetary value of all coffee produce in a year)

A = Amount of land in acres used

L = labor input (the total labour cost in a year)

K = capital input (the monetary worth of all Fertilizers and sprays)

b = total factor productivity

μ, α and β are the output elasticities of acreage, labor and capital, respectively. These values are constants.

Hence, the Cobb- Douglas production function can be re-written in an extended form as follows;

$$P(X_1, X_2 X_3) = aX1^{b1} X2^{b2} X3^{b3} e^{ut} \qquad 4.3$$

Where P is the Coffee output,

A = total factor productivity

X_1 = Coffee farm sizes in hectares

X_2= Quantity of Fertilizers used in a year

X_3 = Quantity of spray chemicals used in a year.

The values given as b_1, b_2, b_3 and ut 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:

$$lnP = lnA + b_1 lnX_1 + b_2 lnX_2 + b_3 lnX_3 + ut \qquad 4.4$$

By getting appropriate data and fitting in into the system, it is then possible to run an econometric estimation by using STATA.

4.6.1 Combined Contribution of Inputs to Coffee Productivity

Table 4.14 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.

Table 4.14: Coffee Productivity using Cobb-Douglas Production Function

	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	

Source: Field Data (2016)

Upon computing the sum of b_1, b_2 and b_3 we get -0.153, 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; these findings agree with Chidoko, et.al. (2011). However, the coffee production technology used in zone UM2 exhibits increasing returns to scale; these findings agree with Nchare (2007). The results presented in Table 4.14 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; the result which agrees with Okoboi (2011) and Cabanilla, et al (2003), 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.

Table 4.15 gives a summary of regression results of coffee productivity when year and zone effects are included using the pooled ordinary linear squares regression technique. The results presented in Table 4.15 gives the estimated F-statistic of 11.99 with a corresponding P-value of 0.0000. This P-value exceeds the critical p-value of 0.05, showing that all the variables included in the model are jointly significant in explaining the variations in coffee output. The adjusted R-squared value of 0.4707, illustrates that 47.07% of the variations in coffee output are accounted for by the model. The results presented in Table 4.15 also indicate that coffee output is positively and significantly related to acreage planted. It also shows that the quantity of triple 17 (17 17 17) fertilizer used is positively related to the coffee output. The coefficient of the variable is also statistically significant.

Table 4.15: 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)

The results presented in Table 4.15 also 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 4.15 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. Similar findings by Bagamba et al (2004) showed 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

4.7 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 4.16.

Table 4.16: 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	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)

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.

4.8 The Percentage Contribution to Coffee Output by the Four Factors

This analyses the percentage contribution to coffee output by the four factors of production. It considers labour input, which is computed at 30% of the total cost of the other three factors. The R-square for this study was 0.06 or 6%. This means that 6% of the coffee output from zone UM1 is explained by the four factors of labour, farm size, fertilizer and spray chemicals when Cobb Douglas production function is used. The remaining 94% is determined by other factors such as extension services and education.

In the case of zone UM2 the R-square was 0.202 or 20.2% which meant that 20.2% of the coffee output from the zone is explained by the four factors of labour, farm size, fertilizer and spray chemicals when Cobb Douglas production function is used. Similarly 32.7% of the coffee output from zone UM3 is explained by the four factors. The average contribution to the coffee output for the period under study for the three zones combined by the four factors is 19.63%.

Table 4.17 gives a summary of the percentage contribution of coffee output per year. For the coffee zones combined the contribution of labour, farm size, fertilizers and spray chemicals to total coffee output per year. The results presented give an average of 19.71% as the average contribution of coffee output. This average compares favourably with the average when considering zones separately.

Table 4.17: Percentage Contribution to Coffee Output Per Year

Year	% Contribution (when Fertilizers and sprays are considered as separate factors)	% Contribution (when Fertilizers and Sprays are considered as one factor)
2004	0.2218	0.2902
2005	0.1932	0.2471
2006	0.1859	0.2377
2007	0.1869	0.2262
2008	0.1759	0.1915
2009	0.2050	0.2187
2010	0.2165	0.2383
2011	0.1280	0.1457
2012	0.1587	0.2502
2013	0.2188	0.3012
2014	0.2779	0.2762
Average	**19.71%**	**23.84%**

Source: Field Data (2016)

4.9 Supply Response of Coffee Production Using the Nerlove Model

In this section, the supply response of coffee production is tabulated and discussed for zone UM1, UM2, UM3 and for all zones combined. 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. 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 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 4.18 gives a summary of the estimation results.

The estimation results presented in Table 4.18 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 4.18 and upon including the price of coffee per Kg in Kshs gives b_o = -363.26, b_1 =7.707, b_2 = 0.831 and b_3 = 0.058. This means that α_1 = 68.977 and α_0 = -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 yields 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, the researcher conducted a joint parameter test for the years and the zones. The results presented in Table 4.18 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.

Table 4.18: 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)

It is evident from the results presented in Table 4.18 that the parameter test for joint inclusion of the years variables in the supply response model is not statistically significant, The results presented in Table 4.18, 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 4.19 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 4.19: 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 Table 4.19 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 gives a b_o = 52.662, b_1 = 1.335, b_2 = 0.644 and b_3 =0.169. Hence, based on equation $\alpha_1 = b_1/ (1 - b_2 - b_3)$, α_1 =7.139. After solving the equation for b_0 and b_1, gives $\alpha_0 = b_0/b_1\alpha_1$=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 $\varepsilon = \alpha_1 \dfrac{\rho}{A} = \alpha_1$ (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 4.20.

The results presented in Table 4.20 give 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 4.20: Supply Response of Coffee Production using Nerlove Model for Zone UMI

Variable	**If Cost of fertilizer is**		**If Cost of spray is**	
Coffee output at time t (A_t)	**Coefficient**	**P-value**	**Coefficien**	**P-value**
Cost of Fertilizer used in Kshs	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 4.20 indicate 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 b_o = 96.366, b_1 = 0.002, b_2 = 0.641 and b_3 = 0.168. Hence, based on equation $\alpha_1 = b_1/ (1 - b_2 - b_3)$, α_1 =0.010. After solving the equation for b_0 and b_1, gives $\alpha_0 = b_0/b_1\alpha_1$=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 4.19, which uses price of coffee as the variable of significance.

Based on the formula $\varepsilon = \alpha_1 \frac{\rho}{A} = \alpha_1$ (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 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 b_o = 64.789, b_1 = 0.027, b_2 = 0.638, b_3 = 0.170, α_1 =0.141 and α_0 = 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 4.21 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 4.21 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.

From the reduced form equation of the Nerlove model and upon including the price of coffee per Kg in Kshs for zone UM2 gives b_o = 346.706, b_1 =-0.398, b_2 = 0.668 and b_3 = 0.108 and hence α_1 =-1.777 and α_0 =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 4.21: 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)

Table 4.22 gives the estimation results of the Nerlove model for UM2 zone based on cost of inputs. The estimation results gives 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 4.22: Supply Response of Coffee Production using Nerlove Model for Zone UM2

Variable	**If Cost of fertilizer is**		**If Cost of spray is**	
Coffee output at time t (A_t)	**Coefficien**	**P-value**	**Coefficien**	**P-value**
Cost of Fertilizer used in Kshs (P_{t-}	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 4.22 indicate 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 b_o = 268.509, b_1 = 0.019, b_2 = 0.626 and b_3 =

0.094 and hence α_1 =0.068 and α_0 =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 b_o = 312.765, b_1 = 0.009, b_2 = 0.658 and b_3 = 0.110. Hence, α_1 =0.039 and α_0 =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 4.23 gives a summary of the results for supply response of coffee production for Zone UM3 using the Nerlove model.

As illustrated in Table 4.23, 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 4.23: 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 b_o =-447.15, b_1 =6.357, b_2 = 1.609 and b_3 =-0.228. Hence α_1 =-16.685 and α_0 =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 4.24.

Table 4.24: 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 Table 4.24 show 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.

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 b_o = -66,513,

b_1 = -0.037, b_2 = 1.764 and b_3 = -0.196. Hence α_1 =0.065 and α_0 = 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 b_o = -155.04, b_1 = -0.025, b_2 = 1.657 and b_3 = -0.232. Hence, α_1 =0.059 and α_0 = 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 4.25 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.

Table 4.25: 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)

The estimation results presented in Table 4.25 give 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 b_o =51.705, b_1 =2.987, b_2 = 0.838 and b_3 =0.055. In this case, α_1 =27.916 and α_0 =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 4.26. The estimation results presented in Table 4.26 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.

Table 4.26: 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)

The results presented in Table 4.26 show 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 b_o = 123.779, b_1 = 0.008, b_2 = 0.817 and b_3 = 0.051. In this respect, α_1 =0.061 and α_0 =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 b_o = 149.528, b_1 = 0.002, b_2 = 0.834, b_3 = 0.055. In this case, α_1 =0.018 and α_0 = 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.

4.10 Coffee Production Trend for the Last Ten Years in Kiambu County

Coffee production in Kiambu County has been cyclical over the years. The trends show, for example, that the total quantity of coffee output was negatively and statistically significant in 2008, showing that the coffee output reduced in 2008 compared to the quantity produced in 2004.

Similarly, coffee output was negatively and statistically significant in the years 2010, 2011 and 2012 relative to the output in the year 2004. This implies that coffee production in UM1 Zone of Kiambu County has been decreasing overtime since the reference year 2004. Table 4.27 gives a summary of the mean coffee production for the various zones.

Table 4.27: 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 4.27 also show 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.

The data presented in Table 4.28 show 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 Table 4.28 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.

Table 4.28: Trends in Coffee Production for Various Years

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Variable	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**
Coffee output in Kgs	1096.744	1240.12	1156.44	1123.272	1075.76	1083.76	1013.928	1121.912	1355.456	1240.544	1296.088
Coffee price per Kg	8.38	24.52	24.99	25.06	25.99	27.76	26.75	73.31	47.6	45.57	37.18
Cost of fertilizer used	9817.28	9430.36	8674.576	8968.16	8456.312	7545.4	6011.04	5054.72	5861.8	6814.48	6157.6
Cost of spray chemicals used	3025.896	2831.432	2826.92	2935.56	2802.48	3149.16	3034.98	3547.34	3540	3757.24	4794.5
Opportunity cost	7312	7387.2	7387.2	7651.2	7651.2	7651.2	8088	8088	8088	8588	8583.2
Labour Cost (30 percent of TC)	6046.5528	5894.6976	5666.6088	5866.476	5672.9976	5503.728	5140.206	5007.018	5246.94	5747.916	5860.59
Total Revenue (TR)	9190.71472	30407.7424	28899.4356	28149.19632	27959.002	30085.178	26075.45	80130.46	58461.49	53995.95	47784.09
Total Cost (TC)	26201.7288	25543.6896	24555.3048	25421.396	24582.99	23849.488	22274.226	21697.078	22736.74	24907.636	25395.89
Profits (TR-TC)	-17011.01408	4864.0528	4344.1308	2727.80032	3376.0128	6235.6896	3801.224	58433.382	35724.75	29088.314	22388.2

Source: Field Data (2016)

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The chapter outlines the key findings of the study, conclusions and recommendations and suggested areas for further research.

5.2 Summary of the Study Findings

The estimation results of coffee productivity using the Cobb-Douglas production function showed that the coffee production technology in zone UM1 exhibited decreasing returns to scale. The computed value of output elasticity was -0.153, which is less than 1. The estimation results showed, however, that the technology used in zone UM2 had an elasticity of 1.029. The measured elasticity in UM2 zones was greater than 1 thus exhibiting increasing returns to scale. In addition, the elasticity for UM3 zone was 0.697 indicating decreasing returns to scale. According to the estimation results of the Cobb-Douglas function, the computed elasticity for the combined zones was 0.647, which is less than 1. This depicts decreasing returns to scale.

The regression results of the pooled OLS regression Model 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 of the supply response based on the Nerlove model showed that coffee output in the current period varies significantly with changes in the coffee output in the previous period and its two-year lag. The long-run price elasticity was estimated at 0.409 for UM1. This implies that a unit change in the price of coffee leads to a corresponding change in coffee output by 0.409 in zone UM1. The results for zones UM2 and UM3, however, shows a negative relationship with parameter estimate of -0.032 and -0.453 respectively. The long run price elasticity for all the zones was estimated at 0.800.

The results also show prices of coffee are statistically insignificant in relation to coffee output for the three zones for the small holder farmers in Kiambu County. Also, there is 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.

In regard to education, the level of primary education and secondary education is positively and statistically significant in influencing coffee output production. Hence, farmers who had attained primary and secondary education realized more output compared to those with no education.

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.

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, 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. 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.

From the study, a unit change in the price of coffee leads to 0.409, 0.032 and 0.453 changes in coffee output in UM1 zone, UM2 zone and UM3 zone respectively. The total quantity of coffee output was negatively and statistically significant in 2008, showing that the coffee output reduced in 2008 compared to the quantity produced in

2004. Similarly, coffee output was negatively and statistically significant in the years 2010, 2011 and 2012 relative to the output in the year 2004.

The study also revealed that a unit change in the cost of fertilizer leads to 0.080, 0.356 and 0.514 changes in coffee output in UM1 zone, UM2 zone and UM3 zone respectively. Similarly, a unit change in spray input contributes to a 0.331, 0.094 and 0.233 change in coffee output in the zones respectively. The total quantity of coffee output was negatively and statistically significant in 2008, showing that the coffee output reduced in 2008 compared to the quantity produced in 2004. Similarly, coffee output was negatively and statistically significant in the years 2010, 2011 and 2012 relative to the output in the year 2004.

On average the farmers in zone UM1 realized a profit of Kshs. 3,438.95; those in zone UM2 realized a profit of Kshs. 14,734.23; while on average the farmers in zone UM3 realized a profit of Kshs. 4,824.17. The farmers not only realized profits but they also witnessed losses of Kshs. 14,025.9 in the year 2004 and Kshs. 34.86 in the year 2007. The highest mean profit of Kshs. 39,401.26 was realized in the year 2011, followed by a mean profit of Kshs. 23,433.24 in the year 2012. It should be noted that the highest mean profit was incurred by the farmers in the year when the average coffee price per Kg was also the highest (Kshs. 73.31).

5.3 Conclusions and Recommendations

In this section we give the conclusions emanating from the study, give the recommendations and also suggest the areas for further research.

5.3.1 Conclusions

The study findings confirm that increases in acreage leads to an increase in coffee output for all zones save for zone UM1. It also shows that 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. In respect to education, attaining basic education (primary and secondary education level) by the farmers is essential for the coffee farmers to enhance their coffee productivity.

From the study, 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. Overall, coffee production in UM1 Zone of Kiambu County has been decreasing overtime since the reference year 2004. Also, the mean profit was positively related to the average coffee price per Kg and hence coffee profits trended with coffee prices prevailing in the specific year.

5.3.2 Recommendations

The study findings and the conclusions made gives rise to the following recommendations:

(a) In order to reverse the downwards coffee output overtime, the government should consider increasing the size of acres under coffee production so as to increase the output. This could be through leasing and contracting of any unused lands to the farmers for coffee farming. In addition land acreage can be increased through both land reclamation and irrigation for coffee production.

(b) The Kenya Government to put measures in place to market and promote Kenyan Arabica coffee in the international market.

(c) Farmers need to increase the quantity usage of compound fertilizer in the form of triple 17, and those who don't use fertilizers have to be encouraged to use it.

(d) To increase coffee output, farmers have to increase the usage of the quantity of spray chemical in the form of copper and desist from using S*umithion* type of spray chemicals.

(e) The government ought to subsidize the cost of fertilizers and copper spray chemicals. This is due to the dynamic nature of relative enterprise competitiveness over time and space. Other innovative ways of lowering cost of inputs could also include the following:

   (i) Bulky purchases of inputs by co-operatives.

   (ii) Regional manufacturing of fertilizers and spray chemicals.

   (iii) Examining the fertilizer value chain and identify opportunities for cost-effective interventions.

(f) Adopt value addition to coffee output so as to increase its value in the international market and hence fetch better prices.

(g) Farmers should be advised to grow shade trees to protect coffee and other crops against extremes of temperature and weather events. They can plant green manure crops and do mulching to reduce their dependence on artificial fertilizers. They can use terracing, ditches and pits to manage water and maintain soil moisture during dry spells. A concentrated effort in educating and training farmers could bring about significant improvements in land management and livelihoods.

(h) Farmers can be trained in agricultural techniques that improve their productivity and livelihoods. Better still, farmers can be trained to train other farmers to do better land and crop husbandry.

(i) 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.

5.4 Areas for Further Research

The following areas are suggested for further research:

(i) There is need to replicate the study to other Counties involved in coffee production to ascertain whether the findings are consistent to those established in Kiambu County.

(ii) Similar studies ought to be conducted in tea production, sugar production, sisal production and other main cash crops in Kenya.

(iii) Studies related to the production of drought resistant crops like cassava, sweet potatoes need also to be conducted.

(iv) Similar research should be conducted to ascertain whether GARCH Model can be used to predict the behavior of future coffee prices.

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APPENDICES

Appendix 1: Questionnaire for small Arabica Coffee Holdings in Kiambu County

This research is conducted for educational purposes and information obtained will be treated with confidentiality and only used for research purposes at the Open University of Tanzania.

Questionnaire number [ ] Date (dd, mm) //2014

1. Farmer's Name and age in years …………………………….………………..
2. Enumerator's name

3. Administrative division…………………………………….…………………

4. Location……………………………………………………..…………..

5. Factory name……………………….Cooperative Society name ………………

6. Profile of household head (hh): tick the appropriate answer
   Sex: Male [ ], Female [ ]

Level of formal education: Primary [ ], Secondary [ ], Post-secondary [ ] State the training or course ______________

Main activity:

(a) Coffee growing [ ]

(b) Tea growing [ ]

(c) Banana growing [ ]

(d) Dairying [ ]

Other farming activities [ ], state the activities

…………………………………………………………………………………………

…………………………………………………………………………………………

Casual work [ ]

Permanent employment [ ]

Other Business (specify)……………………………………………………………

Experience in coffee growing: state the number of years of operation

…………………………………………………………………………………………

…………………………………………………………………………………………

7. Profile of household members

Please provide us with the number of household members under each category below:

Category	Number
1. Lessthan18 years of age	
2. Male and 18-59yearsofage	
3. Female and 18-59yearsofage	
4. Over59yearsofage	

Human Capital

8. For each household member, please provide us with details about their age, years of formal education, their main occupations and years of experience.

Member *(Use 1 for son, 2 for daughter and 3 for others)*	Age in years	Level of education	Main Occupation		Secondary Occupation	
			Name	Years of Experience	Name	Years of Experience

9. Landholdings: What is the form of landholdings and size?

Form of ownership:	Owned with title	Owned without title	Leased in	Leased Out

(a) Distance to the nearest main Coffee Cooperative Society [ ]Kms

(b) Distance to the nearest motorable, all-weather road [ ]Kms

(c) Distance to the nearest main trading centre [ ]Kms

10. Type of main house (tick)

House type (Tick one)

(a) Permanent,

(b) Stone iron-roofed [ ]

(c) Semi-permanent timber, iron-roofed [ ]

(d) Semi-permanent, mud-walled, iron roofed [ ]

(e) Mud-walled, thatched roof [ ]

Others; [ ] Specify

……………………………………………………………………………………………

……………………………………………………………………………………………

11. Enterprise allocation, yield and revenue

Type of enterprise	**Acreage or No. (in case of animals)**	**Indicate 1 for Cash Crop; 2 for Food and 3 for Both**	**Estimated annual Production**	**Units**	**Estimated annual sales (KES)**
Coffee					
Tea					
Maize					
Beans					
Bananas					
Mature cattle (No.)					
Young cattle					

(No.)					
Sheep (No.)					
Goats(No.)					
French beans					
Oranges					
Pawpaw					
Others:					

11. Historical profile of household coffee activity

Year Established	Acreage	Number of trees	Variety:1=Ruiru11, 2=Other varieties

12. Since the year of establishment, have you increased the acreage under coffee?

[ ] Yes [ ] No; If 'YES', fill in the table below:

Year of Expansion	Area in acres under Expansion	Number of Trees	Variety: 1=Ruiru11, 2=Other Varieties	Reasons for expansion: 1=PlantingRuiru11 2=Coffee farming was profitable 3=Others were doing so

13. Since establishment, have you uprooted any coffee? [ ] Yes, [] No; If 'Yes', fill in the table below:

Year Uprooted	Area in acres uprooted	Number of Trees uprooted	Variety: 1=Ruiru11, 2=Other Varieties	Reasons for uprooting: 1=Replacement with another coffee variety 2=Coffee price was low 3=Others were doing so 4=To cut on costs

14. Since establishment, have you ever abandoned or reduced maintenance activity on coffee?

[ ] Yes, [] No; If 'Yes', fill in the table below:

Year abandoned or reduced maintenance	**Reduced activities**			
	Area in acres abandoned	Number of Trees abandoned	Variety: 1=Ruiru11, 2=Other Varieties	Reasons for abandoning: 1=Traditional varieties were unprofitable 2=Coffee price was low 3=Others were doing so 4=To cut on costs

15. Have you ever re-established coffee farming? [ ] Yes, [] No; If ‘Yes’, fill in the table below:

Year re-established	Re-establishment			
	Area in acres re-established	Number of Trees re-established	Variety: 1=Ruiru11, 2=Other Varieties	Reasons for reestablishment: 1= Coffee prices were improving 2=Replacement with another variety 3=Costs were lower due to new technologies 4=Others were doing so

16. What is the spacing and average annual production for each coffee variety?

	Spacing; width Xlength(m)	Total production per year
1. SL28/34/ K7		
2. Ruiru11		
3. Mixed		

FARM INPUTS FOR COFFEE

17. For each fixed investment, please tell us the number, year of purchase, cost and approximate useful life.

Item	Number	Unit cost	Year purchased	Expected usefullife
1.Bags				
2.Secateurs				
3.Knapsack sprayers				
4.Forkedjembe				
5. Pangas				
6. Other (specify):				

18. What is the annual quantity and unit cost of any of the inputs that you have used over the last one year in the coffee field?

		Quantity	**Units**	**Unit cost**	**Total cost**
DAP					
SSP/ 17:17:0					
CAN					
Copper fungicide					
Insecticides					
Herbicides					
Manure					
Mulch					
Fertilizer application labour	1.Family				
	2. Hired				
Manure application labour	1.Family				

	2. Hired				
Weeding labour	1.Family				
	2. Hired				
Spraying labour	1.Family				
	2. Hired				
Coffee pruning labour	1.Family				
	2. Hired				
Tree pruning labour	1.Family				
	2. Hired				
Mulching labour	1.Family				
	2. Hired				
Harvesting labour	1.Family				
	2. Hired				

MARKETS AND INSTITUTIONS

19. Provide information on marketing channels used, annual deliveries and price

Markets	Channel used: 1=Yes 2=No	Price per Kg	Annual delivery (Kgs)
Cooperative			
Brokers			
Private factories			

20. Please provide us with details on extension visits, seminars attended and group membership over the last12months.

Extension Visits, Seminars Attended and Group Membership	**Number**
Extension visits	
Agricultural shows or exhibitions attended	
Agricultural seminars and/or courses/training attended	
Agricultural groups of which you are a member	
Coffee-related groups of which you are a leader	
Coffee meetings attended	
Agricultural awards won	

REVENUES

21. In your opinion, which revenue category best represents your annual earnings (Ksh) from each source? Tick

	0-12,000	12,000-24,000	24,000-36,000	36,000-60,000	60,000-120,000	120,000-300,000	>300,000
Coffee							
Tea							
Selling trees							
Bananas							
Dairy							
Beef							
Sheep							
Goats							
Salary							
Wages							
Rented houses							
Retail business							
Others (Specify):							

SENSITIVITY OF COFFEE ACTIVITIES

22. How does/will the price of coffee affect your coffee farming practices?

Practice	Current price =	Double price =	Halfprice =
Number of manual weeding per year			
Number of herbicide sprays per year			
Number of prunings per year			
Number of desuckerings per year			
Number of fungicidal sprays per year			
Number of insecticide sprays pe ryear			
Number of top-dressings per year			
Number of foliar feed sprays per year			
Number of phosphatic applications per year			
Number of mulching per year			
Number of Prunings of coffee trees per year			

Extra Questionnaires

1. Farmer's Age ___________;Male [ ], Female [ ]
2. Do you attend for Adult education? Do you find it useful for your business? Yes [ ], No [ ]; If yes, how?
3. Have you attended any training? If so which one and for how long and how often? Do you find it useful for your business? Yes [ ], No [ ]; If yes, how?
4. Have you ever been visited by an agricultural extension officer? Yes [ ], No [ ]; If yes, when was it? How often are you visited by extension officers? Is it useful for your coffee farming?
5. Which coffee zone is this?
6. Which coffee variety do you grow?
7. What is the size of your land?
8. What size of your land is planted with coffee?
9. When did you start growing coffee?
10. How long did it take before you started harvesting coffee?
11. Where do you take your coffee after harvesting it? If cooperative society state the name _____________________
12. How many kilograms of the coffee have you delivered to the next coffee chain (Cooperative Society) per year?
13. Has the coffee output been increasing over the years?
14. Do you use fertilizers in your coffee farms? If so which type and what quantities per Year?
15. Do you spray chemicals for your coffee farms? If so which type and which quantities?
16. How many man hours do you use for the whole year in your coffee farm?
17. What farming skills does the manpower you use possess?
18. What type of capital equipment do you use in your farm?
19. What is their estimated cost and their estimated life span?
20. What other variables do you use in the coffee production process?
21. How do you compare the returns of coffee to other crops in your farm?

22. What challenges to you face in dealing with coffee production? (Especially with regard to prices?)
23. Have you ever increased your production only to find prices coming down?
24. Have you ever increased your production and you find prices going up?
25. What plan do you have so that you start get it right as concern price increase in the world market?
26. What policy measures would you like the Government to put in place to improve this sector

Appendix 2: Individual Contribution of Inputs to Coffee Productivity for Various Years

	2004			2005		
Ln Coffee output	Coef	P-value	Exp (coef)	Coef	P-value	Exp (coef)
Ln Farm size Acres	0.173	0.410	1.189	0.087	0.677	1.091
Ln 17 17 17 quantity in kgs	0.069	0.479	1.071	0.579*	0.036	1.784
Ln CAN quantity in kgs	0.017	0.812	1.017	-0.004	0.948	0.996
Ln spray type copper used in litres	0.569	0.217	1.767	-0.103	0.774	0.902
Ln spray type sumithion used in litres	-0.143	0.713	0.866	0.464	0.125	1.590
Primary education	0.599	0.426	1.821	-0.058	0.943	0.944
Secondary education	1.073	0.129	2.923	0.506	0.505	1.659
Post-secondary education	0.625	0.407	1.868	0.515	0.523	1.674
UM2	0.695**	0.070	2.003	0.699*	0.057	2.011
UM3	0.195	0.680	1.215	0.132	0.778	1.141
Constant	4.723*	0.000	112.502	2.936*	0.033	18.836

	2006			2007		
Ln Coffee output	Coef	P-value	Exp (coef)	Coef	P-value	Exp (coef)
Ln Farm size Acres	0.264	0.136	1.302	0.235	0.181	1.265
Ln 17 17 17 quantity in kgs	0.521*	0.003	1.683	0.236	0.157	1.266
Ln CAN quantity in kgs	0.014	0.822	1.014	0.079	0.204	1.082
Ln spray type copper used in litres	0.296	0.543	1.344	0.906*	0.029	2.475
Ln spray type sumithion used in litres	-0.030	0.937	0.970	-0.462	0.172	0.630
Primary education	0.296	0.650	1.344	-0.106	0.923	0.899
Secondary education	0.689	0.249	1.992	0.178	0.865	1.195
Post-secondary education	0.492	0.452	1.636	-0.173	0.872	0.841
UM2	1.225*	0.001	3.404	0.762*	0.042	2.142
UM3	0.519	0.201	1.680	0.077	0.861	1.080
Constant	2.425*	0.014	11.302	4.102*	0.002	60.490

	2008			2009		
Ln Coffee output	Coef	P-value	Exp (coef)	Coef	P-value	Exp (coef)
Ln Farm size Acres	0.074	0.647	1.076	0.068	0.656	1.071
Ln 17 17 17 quantity in kgs	0.186**	0.059	1.204	0.013	0.906	1.013
Ln CAN quantity in kgs	0.089	0.108	1.093	0.170*	0.004	1.186
Ln spray type copper used in litres	0.984*	0.020	2.674	0.416	0.147	1.516
Ln spray type sumithion used in litres	-0.637**	0.075	0.529	-0.064	0.798	0.938
Primary education	0.273	0.766	1.314	0.740	0.445	2.095
Secondary education	0.160	0.857	1.174	0.654	0.486	1.924
Post-secondary education	0.345	0.708	1.411	0.353	0.720	1.424
UM2	0.882*	0.007	2.415	0.946*	0.003	2.574
UM3	0.236	0.522	1.266	0.339	0.326	1.403
Constant	4.380*	0.000	79.803	4.659*	0.000	105.524

	2010			2011		
Ln Coffee output	Coef	P-value	Exp (coef)	Coef	P-value	Exp (coef)
Ln Farm size Acres	0.227	0.140	1.255	-0.048	0.785	0.953
Ln 17 17 17 quantity in kgs	0.023	0.828	1.024	0.065	0.515	1.067
Ln CAN quantity in kgs	0.105**	0.091	1.111	0.160*	0.004	1.174
Ln spray type copper used in litres	0.142	0.690	1.152	0.588*	0.046	1.800
Ln spray type sumithion used in litres	-0.095	0.733	0.909	-0.330	0.159	0.719
Primary education	-0.822	0.272	0.439	0.900	0.177	2.460
Secondary education	-0.806	0.267	0.447	0.662	0.285	1.939
Post-secondary education	-1.415**	0.073	0.243	0.825	0.231	2.282
UM2	1.292*	0.000	3.639	1.234*	0.001	3.435
UM3	0.456	0.267	1.578	0.314	0.412	1.369
Constant	6.238*	0.000	511.726	4.336*	0.000	76.386

	2012			2013		
Ln Coffee output	Coef	P-value	Exp (coef)	Coef	P-value	Exp (coef)
Ln Farm size Acres	0.143	0.387	1.154	0.577*	0.006	1.781
Ln 17 17 17 quantity in kgs	0.069	0.389	1.071	-0.145	0.218	0.865
Ln CAN quantity in kgs	0.107*	0.045	1.113	0.021	0.766	1.021
Ln spray type copper used in litres	0.590**	0.078	1.804	-0.029	0.941	0.971
Ln spray type sumithion used in litres	-0.408	0.126	0.665	-0.099	0.754	0.905
Primary education	0.806	0.212	2.238	0.484	0.715	1.623
Secondary education	0.448	0.463	1.566	-0.159	0.898	0.853
Post-secondary education	0.329	0.610	1.390	-0.528	0.692	0.590
UM2	1.545*	0.000	4.688	0.566	0.214	1.761
UM3	0.910*	0.021	2.484	0.924*	0.036	2.519
Constant	4.322*	0.000	75.342	6.692*	0.000	805.755

	2014		
Ln Coffee output	Coef	P-value	Exp (coef)
Ln Farm size Acres	0.161	0.524	1.175
Ln 17 17 17 quantity in kgs	-0.008	0.955	0.992
Ln CAN quantity in kgs	0.051	0.583	1.053
Ln spray type copper used in litres	0.292	0.567	1.339
Ln spray type sumithion used in litres	-0.207	0.657	0.813
Primary education	0.446	0.696	1.562
Secondary education	-0.056	0.959	0.945
Post-secondary education	0.579	0.611	1.783
UM2	0.572	0.331	1.771
UM3	0.623	0.319	1.865
Constant	5.503	0.000	245.375