ANALYSIS OF DEMAND FOR ANTIBIOTICS IN POULTRY PRODUCTION IN KIAMBU COUNTY, KENYA

MBUGUA MERCY WANJIRU

A thesis submitted in partial fulfillment of the requirements for the award of Master of Science degree in Agricultural and Applied Economics,University of Nairobi

DECLARATION

This thesis is my original work and has not been presented for award of a degree in anyother University.

Mbugua Mercy Wanjiru, BSc (Agricultural Economics Option) (Hons), Nairobi

Candidate (Reg. No.A56/60402/2011)

Signature…………………………………. Date……………………………………..

This thesis has been submitted with our approval as University supervisors:

Dr.Patrick Irungu

Lecturer

Department of Agricultural Economics

University of Nairobi

Signature……………………………………. Date…………………………………………….

Dr. Jonathan Nzuma

Lecturer

Department of Agricultural Economics

University of Nairobi

Signature……………………………………. Date………………………………………

DEDICATION

I dedicate this thesis to my loving parents, Mr Evans and Mrs Jane Mbugua. It is through your encouragement, timely advice and prayers that I have made it this far. Thank you for every sacrifice you made just to see me excel in my academic career. May God Almighty bless you and give you more days to enjoy the fruits of your commitment and sacrifice.

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ACRONYMS AND ABBREVIATIONS

3SLS - Three Stage Least Square

AERC - Africa Economic Research consortium

AIC - Akaike information criterion

CES - Constant Elasticity of Substitution

DOC- Day old chick

FAO - Food and Agriculture Organisation

FAOSTAT - Food and Agriculture Organisation Statistics

FGLS - Feasible Generalized Least Squares

GARP - Global Antibiotics Resistance Partnership

GDP - Gross Domestic Product

GL - Generalized Leontief

GoK - Government of Kenya

KNBS - Kenya National Bureau of Statistics

MLE - Maximum Likelihood Estimate

OLS - Ordinary Least Squares

RoK - Republic of Kenya

SPSS - Statistical Package for Social Science

SUR - Seemingly Unrelated Regression

VES - Variable Elasticity of substitution

VIF- Variance Inflation Factor

ABSTRACT

Poultry production is an important economic activity for smallholder farmers in Kenya. Commercial poultry farming in Kenyarelies heavily on veterinary inputs, key among them being antibiotics which develop resistance with improper use. Among the many interventions used in the past to curb the risk of antibiotic resistance in livestock in Kenya, there is none that has comprehensively addressed inappropriate use of antibiotics and the incentives driving their demand in the livestock industry. This study, therefore,characterized antibiotic use patterns in poultry production and assessed the responsiveness of antibiotic demand to factor and product price changes in Kiambu County of Kenya. The aim was to generate information which can be used to enrich policy design geared towards reducing the risk of antibiotic resistance in the livestock sector in Kenya.

A sample of 238 commercial chicken farmers in Kiambu County was selected using a multistage sampling procedure.Primary data were collected using semi-structured questionnaires. Descriptive statistics were done to characterize the patterns of use for antibiotics. A normalized restricted translog profit function was also used to estimate own-price and cross-price elasticity of antibiotic demand in layer and broiler production systems in Kiambu County.Descriptive statistics done to characterize the pattern of use for antibioticsindicated that: (i) antibiotics were widely used in poultry production in Kiambu County, (ii) they were accessible to farmers, mainly from agro-vet shops and (iii) Farmers administer antibiotics without the assistance of professional veterinary personnel. The implication is that these practises increase the likelihood of drug misuse and therefore the probability of increasing antibiotic resistance in poultry.

Results from the econometric model showed that the own-price elasticity of antibiotic demand for both layer and broiler production systems were negative, more than unity (-1.7 for broiler and -1.2 for layers) and statistically significant ($p<0.05$), implying that manipulating antibiotic prices is, potentially, an attractive strategy to control antibiotic use.On the other hand, the cross-price elasticities of antibiotic demand were not statistically significant ($p>0.05$), implyingthat the cross prices cannot be used as a strategy to regulate antibiotic use.Additionally, antibiotic demand was positive and most sensitive to producer egg and chicken meat prices, which meant that most farmers would use egg boosters and growth promoters with increased egg and chicken meat prices.

Theresults indicated that rational use of antibiotics could be strengthened by the policy makers manipulating antibiotic prices. Increasing the prices of antibiotics to reduce the demand through an antibiotic "pigouvian" tax policy can achieve a significant reduction in antibiotic use. Also, given the high and positive output price elasticities, farm output price supportwould be unlikely to reduce antibiotic use in poultry production in Kiambu County.Therefore, supporting the activities of the Pharmacy and Poisons Board and the Department of Veterinary Services in monitoring and regulating the use of antibiotics as egg boosters in layers and growth promoters in broilers is likely to reduce the overall risk of development of antibiotic resistance in poultry in Kenya.

CHAPTER ONE

INTRODUCTION

1.1 Background

Poultry production is one of the most important economic activitiesamong smallholder farmers in Kenya. It contributes about six percent of the livestock sector's gross domestic product (GDP), two percent to the agricultural GDP and 0.7 percent to total GDP and employs two to three million people (Omiti and Okuthe, 2009).Home consumption of poultry eggs and meat contribute to household nutrition while income from sales of eggs, meat and manure contribute to household food security. As well, poultry often form the first rung in the pathway out of poverty particularly among child-headed households, the elderly and the invalids (Kristjanson *et al*., 2004).

In Kenya, the per capita consumption of poultry meat and eggs is 1.1 kg and 37.5 kg per annum respectively (Omiti and Okuthe, 2009).Poultry production in Kenya is divided into two main production systems depending on type of breed. Exotic breeds are mostly kept in the commercialpoultry production system while indigenousor backyard production system is dominated by indigenous poultry. According to the latest population and housing census, Kenya had 25.8 and 6.1 million indigenous and commercial chickens respectively in 2009, implying that indigenous chicken constitute the largest proportion of the national poultry population at 81 percent (KNBS, 2010).

The Foodand Agriculture Organization of the United Nations (FAO) classifies poultry in Kenya into four productionsystems based on the level of biosecurity and the degree of commercialization. These are: (i) industrial and integrated production system, (ii) commercial production system, (iii) semi-commercial production system, and (iv), traditional or free range or backyard production system.The industrial and integrated production system is characterized by exotic birds, high bio-security, high reliance on purchased feeds and veterinary inputs, export orientation, and it targets high-end local markets (FAO, 2008).

The commercial production system is less industrialized compared to the industrial and integrated system. However, it is more commercialized compared to both the semi-commercial and the indigenous systems. Like the industrial sector, the commercial system is characterized by the rearing of exotic birds, moderate to high biosecurity, high reliance on purchased feeds and veterinary inputs and it targets low- to medium-end local markets. The semi-commercial system is characterized by exotic birds, low-to-minimal biosecurity, moderate reliance on purchased feeds and veterinary inputs and it targets live bird markets in urban and rural areas. Finally, the indigenous/free range system is the largest but with lowest biosecurityand also the least commercialized.

Most of the commercial poultry production systems in Kenya are concentrated around cities such as Nairobi, Kisumu and Mombasa, and major urban centres like Nakuru, Thika and Kiambu where access to markets is assured(Okello *et al.,* 2010).The commercial hybrid production system is further divided into layer and broiler sub-systems. Broilers constitute 16.2 percent of total commercial poultry while layers account for 7.8 percent (RoK, 2008).The former districts of Kiambu, Thika, Nairobi, Nakuru and Kisumu districts produce broilers in large numbers while layer production is concentrated in Kiambu, Thika, Maragua, Nakuru, Nairobi and Kilifi districts (Nyaga, 2007). In most households, the commercial chicken are owned and fed by women; men are responsible for the slaughter and marketing of broilers. Poultry farmers obtain most feeds and drugs from agro-vets, such that, shop selling veterinary drugs and other agricultural inputs(Okello *et al.,* 2010).

Poultry farmers source day-old chicks (DOC) from hatcheries which are found mostly in peri-urban areas of major towns and cities. According to Okello *et al.* (2010), the major hatcheries in Kenya are: Kenchic and Sigma supplies in Nairobi, Muguku in Kikuyu and Kenbird in Naivasha.Each of the chicken hatcheries, rear between 10,000 and 12,000 breeder layersand between 10, 000 and 18,000 breeder broilers per year.These breeders produce between 300,000 and 800,000 day old layer chicks and 750,000 to 1,200,000 day old broiler chicks per year (Omiti and Okuthe, 2009). Farmers place their orders for day old layer and broiler chicks with the respective hatcheries and later collect the birds on the due dates (Okello *et al.,* 2010).

Broiler chickens in Kenya are produced on both large and small scales. On average, large scale farmers keep between 1,000 and 2,000 birds per cycle while small scale farmers rear between 100 and 600 birds per cycle (Nyaga, 2007). In urban and peri-urban areas, about 99 percent of the broilers are sold dressed while the remaining one percent is sold as live birds (Omiti and Okuthe, 2009). Slaughtering of broilers is done at home without any inspection by veterinary or medical personnel (FAO, 2007). There are various marketing channels through which farmers sell their broilers, namely, other farmers, rural and urban retailers, rural and urban brokers and rural and urban wholesalers(Okello *et al.,* 2010).

Egg production for most commercial farmers is done all year round. Most commercial layer producers keep between 100 and 1,000 birds (Nyaga, 2007). Farmers with 500 birds collect on average, 13-15 trays per day for the first 15 months and then production declines to six trays per day during the last two months (Okello *et al.,* 2010).Most of the eggs are sold in local markets where rural wholesalers buy in bulk from rural assemblers who then sell to urban-based brokers (Okello *et al.,* 2010).

There are several fixed and variable inputs involved in commercial poultry production which include infrastructure, DOC, feed, labor and vaccines. Feeds constitute 60 to 70 percent of total production cost(Okello *et al.*, 2010). One of the major constraints to poultry production in Kenya is high incidence of diseases, the major ones being bacterial. The most common bacterial diseases in poultry are fowl typhoid, fowl chorela, pollorum colibacillocis, salmonellosis, infectious corrhyza and mycoplasmosis (Nyaga, 2007). These diseases are almost exclusively controlled using antibiotics. Fowl cholera is one of the very common diseases with high mortality rate of about 30 percent of the flock, contiguous and hard to treat. Pollorum and fowl typhoid are also common but with medium mortality rate of about10-30 percent and/or difficult to treat (Infonet- biovision, n.d)

Antibiotics are damage control inputs whose role is to reduce potential output loss; that is, to bridge the gap between the potential and the actual yield (Lichternberg and Zilbermann, 1986). They belong to different classes depending on the type of the active ingredient. The main classesare tetracycline, sulfonamides, aminoglycosides, quinolones, penicillin and streptomycin.According to Mitema *et al.* (2001), the average annual antibiotic consumption among various livestock types is 75 percent (representing 10,989kg of active ingredient) in large animals, 20 percent (2,906kg of active ingredient) in poultry alone and five percent (699 kg) in both large animals and poultry.

One of the distinguishing features of damage control inputssuch as antibiotics is that the damage agentdevelops resistance with improper use.Recent studies indicate that the problem of antibiotic resistance in Kenya's livestock sector is increasingmainly due to misuse (either overuse or underuse) of antibiotics (Ogara*et al*., 2011; Irungu, 2011; Kariuki *et al*., 2013). This therefore calls for concerted efforts to reduce the growing risk of antibiotic resistancewhichif left unattended, can lead to devastating human and environmental impacts through the food chain (Cerniglia and Kotarski, 2005).

1.2 Problem Statement

Use of antibioticspermits higher levels of livestock production which safeguards the livelihoods of millions of livestock owners in Kenya and also improves animal welfare through positive animal health outcomes. However, improper use of antibiotics in livestock production can cause adverse human health effects due to transmission of antibiotic resistant bacteria through either the food chain or environmental contamination.For instance,recently Irungu (2011)in a study of antibiotic resistance in meat samples collected in the peri-urban Nairobi area found high levels of resistance to most of the antibiotics classes used in poultry farming. The study also showed that the resistance was highly correlated to the pattern of antibiotic use.

There has been increased concern by the government and the public on the issue of antibiotic resistance in the recent years due to increased sensitivity of consumers to food quality and safety especially with regards to veterinary inputs used on livestock (GARP, 2011). As a result, several interventions have been implemented in Kenyain an effort tocurbthe problem of antibiotic resistance such as prohibition of use of critical antibiotics as growthpromoters (as opposed to therapeutic uses) in livestock. However, none of these efforts has comprehensively addressed the fundamental drivers of antibiotic resistance, namelythe improper use of antibiotics,which is based onthe incentives available to antibiotics consumers (farmers in this case).

Based on theliterature reviewed, very little research has been done on use patterns of antibiotics in poultry production in Kenya. For instance, it is only Mitema *et al*. (2001) who documented the national consumption of antibiotics in livestock for the 1995-1999 period. In particular, no study to the author's knowledge has evaluated the responsiveness of demand for antibiotics used in poultry production to price changes in Kiambu County. There is, therefore, a need for a systematic empirical analysis of antibiotic demand in livestock production to gauge how the price incentivesaffect the consumption behaviorin order to informpolicy on strategies that could be used to curb the risk of antibiotic resistance in Kenya. Theoretically, information on the price elasticity of demand for a given commodity can potentially be used as a tool for influencing consumption behavior.This is also true for veterinary antibiotics.

1.3 Purpose and Objectives of the study

The purpose of this study was to understandantibiotics usage and the determinants of their demand in poultry production in Kiambu County, Kenya.The specific objectives of the study were:

1.To characterize antibiotic use patterns in poultry production in Kiambu County.

2.To assess the responsiveness of antibiotic demand in poultry production to price changes in Kiambu County.

1.4 HypothesisTested

The following hypotheses were tested:

1. That antibiotic use among poultry farmers in Kiambu County is homogeneous.
2. That the own-price elasticity of antibiotic demand in Kiambu County is positive.
3. That the cross-price elasticity of antibiotic demand in Kiambu County is positive.

1.5 Justification

The study focused on poultry because it is not only an important source of animal protein in Kenya but also an important and rapidly growing economic activity among smallholder livestock producers in the country. In Kenya, eggs contribute 0.4 per cent of per capita consumption of animal proteins ranking third after milk, bovine meat and mutton/chevron while poultry meat contributes 0.2 percent ranking fourth (FAOSTAT, 2012).Additionally, the importance of poultry as a source of animal protein is expected to increase.For example, poultry meat consumption is expectedto more than double from 376,200 metric tons (MT) in 2010 (2kg per capita) to 1,124,505 MT in 2020 (4.5 per capita) (PSPK, 2010). This increase is due to, *inter alia*, increasing subdivision of land to accommodate the ever-growing human population, increasing urbanization and increasing per capita disposable incomes.

The study was carried out in Kiambu County because according to KNBS (2010), it had the highest number of commercial chicken in 2009 totalling 1,831,427 or about 30 per cent of the total population of commercial chicken in Kenya. According to FAO (2008), commercial chicken is among the poultry classifications that use most of the veterinary inputs, antibiotics included. Therefore, carrying out the study in areas with majority of the commercial chicken enabled the study to capture all the necessary information on antibiotics.

By analyzing the demand for antibiotics in poultry production, this study aimed to provide information that can be used by policy makers in Kenya including the Department of Veterinary Services and the Pharmacy and Poisons Board, to influence the consumption of veterinary antibiotics in poultry production as one of the ways to curb the growing threat of antibiotic resistance both in livestock and humans. Also, the information on the patterns of use can be used as a benchmark for future monitoring of antibiotics consumption for poultry in Kenya. The application of a seemingly unrelated regression (SUR) model in a livestock production context to estimate the profit function from which the price elasticity of antibiotic demand is derived is novel and it constitutes one of the main contributions of this studyto scientific knowledge.

CHAPTER 2

LITERATURE REVIEW

2.1Theoretical Review

2.1.1 Profit function approach to input demand

There are two approaches to demand analysis; the first is estimation of input elasticities directly from a production function, which is termed as a "primal approach" in production economics literature(Diewert, 1971).This methodinvolves postulating a functional form for the production function and then using Lagrangian or programming techniques to obtain the derived demand functions.Parameters of the production function are estimated and the factor equation demands are derived analytically by imposing the assumptions of profit maximisation.

One of the advantages of the primal approach is that it uses data on quantities which are easy and more accurate to capture compared to factor price data used in the "dual" approach (explained below), particularly in developing countries where price data are poorly kept. However, amongst other limitations with the primal approach, simultaneity bias occurs between inputs and outputs especially when working with non-experimental data (Colman, 1983). This bias arises from the simultaneous determination of quantities of inputs and output (Lau and Yotopoulos, 1972).

The second approach is the estimation of input elasticities indirectly from a profit or cost function, also known as the "dual approach". This involves postulating a functional form for the cost or profit function and obtaining derived demand functions by differentiating the cost or profit function with respect to input prices (Diewert, 1971).The duality between production and cost or profit function is assumed provided that the function satisfies regularity conditions[1]. This implies the existence of one- to-one correspondence between the two functions such that either the cost or profit function can be used to derive the properties of the production function (Pope, 1982).

The dual approach is mostly used where there is limited information on relevant primal variables and possible estimation problems associated with the production function. This approach offers a simple way of deriving input and output supply systems directly from either a profit or a cost function. One of the advantages of the duality approach is the ability to accommodate a multiple output as well as a multiple input framework (Tocco *et al*., 2013).A potential problem with this approach is that regardless of the particular functional form chosen, factor price data available for estimation may be of poor quality relative to the data available on factor and/or output quantities (Pope, 1982).

Vijverberg *et al.* (1997) argued that the profit function approach, in general, performs better than either the production function or cost function approach. The profit function provides additional flexibility as the hypothesis of exogeneity of output, found within a cost function framework, is relaxed and the supply function is considered endogenous (Shah, 1992).According to Yotopoulos *et al.* (1976), in every given situation, the profit function approach gives reasonable parameters of the production function unlike parameters given by direct estimation of elasticities from the production function. The elasticities from the profit function approach are statistically consistent (Lau and Yotopoulos, 1972).

Additionally, working with the profit function makes it possible to derive both the output supply function and the factor demand functions without an explicit specification of the

[1]These are conditions that a profit function must satisfy for it to contain sufficient information to completely describe the production technology involved.

corresponding production function, which provides great flexibility in empirical analysis.Another advantage of the profit function approach is that the profit and supply functions as well as the derived factor demand functions obtained may be explicitly written as functions of variables that are normally considered to be determined independently of the firm’s behaviour(Sadoulet and Alain, 1995).This implies that, these variables are exogenous and therefore, by estimating these functions directly, the problem of simultaneous equation bias, if present, can be avoided.

When using the profit maximization approach, producers are assumed to maximise profit subject to a given state of technologyand a mix of fixed inputs. Thus, the producer problemis to choose the level of inputs and output that will maximise the profits given the constraints. The basic assumption required when modelling production possibilities with a profit function approach are that producers are profit maximizers and markets are duly competitive (Higgins, 1986). From the profit function, the factor demand function isderived viathe Hotelling’s lemma and eventually input price elasticities can be estimated(Sadoulet and Alain, 1995). Based on these arguments, the current study adopted the dual approach,involving profit maximization,as opposed to the cost minimization approach.

2.1.2 Functional formsfor profit functions

When estimating the profit function, several function forms have been assumed in previous studies. Theseinclude,Cobb-Douglas, constant elasticities of substitution (CES), variable elasticity of substitution (VES), nested-CES and the translog (Chaudhary *et al.,* 1998). Although, the Cobb-Douglas profit function is easier to work with and make calculations on it, (Ramskov and Munksgaard, 2001), itis based on highly restricted assumptions, which include the unitary elasticity of substitution, constant returns to scale, and *a priori* imposition of separability restrictions(Christensen *et al*., 1971).Thus, the function yields invalid elasticities which fail to explain genuine relationships between inputs and output (Diewert, 1974). The estimates of elasticities therefore are not robust enough to accurately predict producers' responsiveness to input and output prices and thereby for formulating effective policy interventions. In this case, more flexible profit functions are desired.

The CES, the VES and the nested CES are regarded as superior to the Cobb-Douglas profit function. For instance, in these functions, prices of all inputs influence the demand for each input unlike in a Cobb-Douglas profit function where only the price of the input itself influences demand (Ramskov and Munksgaard, 2001).They are,however,also based on rigid restrictions. For example, the CES profit function yields a constant, though not unitary, value for the elasticity of substitution while its nested form involves arbitrary aggregation of independent variables (Chaudhary *et al.*, 1998).

The disadvantage of using functional forms that are more restrictive is that more exogenous parameters are specified. This might cause problems as it is not always easy to find realistic data to determine the parameter values(Ramskov and Munksgaard, 2001). Therefore, these production functions are characterized by weaknesses that are incapable of explaining the exact relationships among variables (Chaudhary *et al.*, 1998). The challengesin the more restrictive functional forms haveled tothe adoption of more flexible ones in analyzing input demand and output supply, such as the translog profit function.

The translog specification is a second degree flexible function in prices and fixed inputs with variable elasticities of substitution and is considered as a second order approximation of any functional form. Its estimation imposes no restriction; it integrates the input demand functions with the output supply function and uses input prices rather than input quantities. It therefore does not involve the problem of aggregation which is associated with input quantities (Chaudhary *et al.*, 1998).

The translog profit function has both linear and quadratic terms with the ability of using more than two factor inputs (Christensen *et al.*, 1973). It also has an additional beneficial property;that differentiating the function with respect to input or output price (or what is known as the Hotelling's lemma), gives the profit share equation for that specific input or output. The profit shares are the basicforms used to compute price elasticities of inputs and output (Christensen *et al.*, 1973).However, although these less restrictive functional forms are more desirable, they often require more information and thus may come at the expense of parameter estimation (Tocco *et al.*, 2013). The current study adoptedthe translog profit function because of its flexibility and ability to use more than one factor.

2.2 Empirical Review

Irungu (2011) analysed the economic incentives influencing farmers' use of antibiotics in livestock production in Kenya. The study used descriptive statistics to document farmers' motivations for use of antibiotics in livestock production in Kenya. Correlation analysis was undertaken to establish the degree of association between livestock farmers' antibiotics use practices and the patterns of drug resistance found in animal samples collected from farms and slaughterhouses in the peri-urban areas of Nairobi City. The study found widespread use of antibiotics among livestock farmers.

Over 80 percent of the farmers interviewed in Irungu's study administered antibiotics without the supervision of qualified veterinary personnel. Antibiotics were mainly used either for treatment or preventive purposes but not for growth promotion. In addition, farmers believed that competition from other producers did not induce more use of antibiotics.

The difference between Irungu's study and the current study is that the former used descriptive analysis to document farmers' motivations for use of antibiotics in livestock production in Kenya whilethis study used a more quantitative econometric analysis to estimate the price elasticity of antibiotic demand in Kiambu County. It is worth noting that although simple descriptive statistics provide important information on behavioural trends, they do not offer much insight into the underlying complex interrelationships and behaviours driving observed phenomena as quantitative analyses do, which is the case in this study.

Bayramoglu and Chakir (2010) analyzed the impact of high crop prices on use of pesticides in France. Panel data were used to measure the impact of high prices of rapeseed due to biofuel policies on the use of pesticides. The study used the profit approach and a log-log specification for pesticide demand to directly obtain the estimates of own-price elasticity of demand. The study found that a one percent increase in the price of rapeseed increased the demand for pesticides by 0.1 percent. The study concluded that the two policies provided by European Union, that is, promotion of biofuel through increased biofuel crop prices such as rapeseed, and restriction of pesticide use were conflicting because high rapeseed prices had a positive effect on pesticide use.

The relevance of Bayramoglu and Chakir's study to the current study is that it usedthe profit function approach to estimate input demand which informed thecurrent study's theoretical approach. Italso emphasizedthe importance of understanding the use of damage control inputs in policy making because their misuse may lead to environmental degradation which was among the factors that motivated the current study. While Bayramoglu and Chakir's study is a useful reference for the current study, it adopted a log-log specification for pesticide demand equation so as to obtain the elasticity of the pesticide directly. In contrast, the currentstudy adopted a translog profit function where elasticities were obtained via the Hotelling's lemma. The reason for choosing thetranslog function is that it has convenient properties of being flexible both in the sense of allowing for theoretical restrictions to be tested and offering a second order approximation of any functionin contrast with the log-log function.

Olwande *et al.* (2009) analyzedthe supply responsiveness of maize output to price and non-price factors and how fertilizer and labour demand responded to changes in prices and non-price factors in Kenya. A normalized restricted translog profit function was used to estimate maize supply and variable input demand elasticities. The study found that a 10 percent increase in maizeprice resultedin 1.1 percent increase in maize supply, holding the prices of variable inputs and the quantities of fixed inputs constant. The variable input prices had a negative effect on maize output while land had a positive effect. Further, the study found that a 10 percent increase in fertilizer prices decreased the demand for fertilizer by 1.2 percent while own-price elasticity of labour was found to be 0.38 in absolute terms.Olwande *et al.* (2009) concluded that making fertilizer prices affordable to smallholder farmers and encouraging more intensive use of productivity-enhancing inputswas desirable. Additionally, high maize prices hurt the welfare of smallholder farmers.

Olwande *et al.* (2009)'s study is similar to the current study in that it used a normalized restricted profit function to estimate the output supply and input demand functions through the Hotelling's lemma. However, other than just estimating the factor demands only as is the case in this study, Olwande's studywent further to estimate the supply responsiveness. Olwande's study therefore informed the theoretical and empirical frameworks of this study because it useda similar dual (reduced form) approach.

Mamatzakis (2007) analyzed the impact of public infrastructure on productivity of Mexican economy. The study used a dual profit model to estimate the effects of infrastructure on economic performance in terms of gains in profits, cost savings, as well as productivity growth enhancement. The restricted translog profit function was used to estimate the effects of infrastructure capital on productivity and on the production structure of Mexican industries. A system of 26 equations was estimated with iterative SUR to account for contemporaneous correlations of error terms. The study found that the contribution of infrastructure to profit was positive while its contribution to cost was negative. However, the impact of infrastructure on both profit and cost was found to decline over time. The study concluded that productivity growth of Mexican industries cannot be attributed to technical change and scale economies alone. However, Mexico's productivity growth was found rather unsatisfactory.

Mamatzakis's study used a similar approach asthe current study in estimating factor demand elasticities using the profit maximization approach and also using a translog profit function as a true approximation of the profit function. It therefore informed the current study's theoretical basis as well as its empirical procedure of estimating a profit function. Mamatzakis's study,however, was done at a macro levelusing time series data unlike the current study which was basedon micro-level cross-sectional data.

Geijer *et al.* (2009) analyzed the potential conflict between Sweden's 16 environmental objectives of sustainable forests in reducing climate change impacts using a forest sector model with profit maximization. The model allowed technical development and lags in price adjustments. This meant that if the price changed, the demand did not necessarily adjust completely within one period.A restricted generalized Leontief (GL) profit function was used and Hotelling's lemma applied to derive the system of supply and demand equations. The results showed that an increase in forest conservation decreased the supply of forest fuels. Assuming that the substitute for forest fuel is fossil fuels (oil), the decrease led to an increase of Swedish emissions of carbon dioxide by almost 1.3 percent, or a 1.05 percent increase in total emission of greenhouse gases calculated as carbon dioxide equivalents.

The study concluded that a serious goal conflict existed between environmental objectives of sustainable forests and reduced climate change impact.Geijer *et al.* (2009)'s study used a system of demands using a restricted GL profit function to derive input and output demand elasticities while the current study useda single equation to estimate demand using a translog profit function. The two studies are similar methodologically in that both usedthe profit maximization approach to estimate the elasticity of demand. Geijer'sstudy therefore forms an important theoretical basis for the current study.

2.3 Summary

From the literature reviewed, only Irungu's study focused on antibiotics use in livestock production. Even then, Irungu'sstudy was a descriptive one and did not empirically test the impact of price elasticity on antibiotic demand. Additionally, most of the other empirical studies reviewed in this study use the dual approach to estimate factor demand, which the current study also adopted in particular focusing onthe flexible translog functional form. As the literature shows, the translog has both linear and quadratic terms with the ability of using more than two factors, which makesit attractive for use in the current study.

CHAPTER 3

METHODS AND DATA

3.1 Theoretical framework

Neo-classical producer theory postulates that firms (or producers) aim to maximize profits subject to technological constraints (Varian, 1992). In such a case, there are two elements used to determine producer's responsetowards achieving the profit maximization objective. One is the technological relationship that exists between any particular combination of inputs and the resulting levels of outputs, which is often represented by a production function in production economics literature. The other is producer's behaviorwith respect to the choice of inputs used to produce a desired level of output, given prices of factors and products as well as the availability of fixed resources (Debertin, 1986).

The combination of factor and product quantities with their corresponding market prices mentioned above leads to the definition of profit, which gives the maximum returna producer, can obtain under given environmental conditions. According to Lau and Yotopoulos (1972),the profit maximization approach specifies the production function as:

$$h(\mathbf{q}, \mathbf{x}, \mathbf{z})=0 \qquad (3.1)$$

where**h**is the technology function, **q** is a vector of output quantityand is also given as $\boldsymbol{q}=f(\boldsymbol{x}, \boldsymbol{z})$;**x** is a vector of variable factors while**z** is the vector of fixed resources. In this formulation, the restricted profit function, which is of importance in this study, is written as:

$$\boldsymbol{\pi}=\boldsymbol{p'q}-\boldsymbol{w'x} \qquad (3.2)$$

where**p'** and **w'**are the respective transposed vectors of product and factor prices. In this study,**p'**represented the vector of unit price of eggs and chicken meat in layer and broiler productionsystems respectively while**w**' wasthe vector of variable input prices such as feed, labour and antibiotics.

Under the neo-classical tradition, the producer's problem is to choose the input and output requirement set that maximizes profit subject to technological constraints (Varian, 1992), i.e,

Max ($\boldsymbol{p'q}$-$\boldsymbol{w'x}$) (3.3)

s.t.$h(\boldsymbol{q, x, z})=0$.

The solution to the producer's problem is a set of input and output supply functions or **x**=**x** (**p**, **w**, **z**) and **q=q(p**, **w**, **z**), respectively(Sadoulet and Alain, 1995).

Equation system (3.3) should ideally satisfy the following conditions for it to contain sufficient information to completely describe the production technology (Lau, 1978):(i) non-negativity, (ii) increasing in output prices, (iii) decreasing in input prices, (iv) convexity, and (v) homogeneous of degree one in all fixed factors. If the profit function satisfies the five conditions, then it is a dual function of the production functionsuch that a well-behaved profit function will be equivalent to a well-behaved production function (Diewert, 1974).

When dealing with a single output, the normalized profit function represents the ratio of the profit function to the price of output; hence it is a function of relative input prices (Sadoulet and Alain, 1995), such that:

$\pi^*=\pi^*(\boldsymbol{p^*, w^*, z})$ (3.4)

where$\boldsymbol{w}* = \frac{w_i}{P_y}$and $\boldsymbol{p}* = \frac{P_i}{P_y}$.

From the profit function (Equation 3.4), a system of output supply and input demand functions can be obtained by differentiating the profit function with respect to output and input prices respectively, or what is called the Hotelling's lemma(Christensen *et al.*, 1973).This is expressed as:

$$\frac{\partial\pi *}{\partial pi *} = \boldsymbol{q} \text{and} \frac{\partial\pi *}{\partial wi *} = -\boldsymbol{X_i} \qquad (3.5)$$

where**q**and **x** are the output supply and input demand functions respectively.

According to Diewert (1974), the supply and demand functions should satisfy two conditions: (i) symmetry condition, such that,the cross-price elasticities are inversely proportional to the corresponding profit share,and (ii) homogeneity condition, such that,the sum of elasticities of any output or input with respect to all prices should equal zero for a constant returns-to-scale production function and that the sum of its elasticities with respect to the fixed factors should equal unity. The two restrictions are important in two main ways: first, they are used to examine the underlying theoretical fundamentals about how a profit maximizing firm would respond to changes in its economic environment. Second, they are used to empirically decide whether a particular firm's observed behavior is consistent with a profit maximizing model (Varian, 1992).

There are several difficulties associated with formulation and estimation of a profit function. The first problem pertains tothe fact that the technology cannot be described by a twice continuously differentiable production function and therefore the derivatives from Hotelling's lemma may be inappropriate. A differentiable function such as translog is often used to solve for this problem in empirical work. The other problem arises in absence of aprofit maximizing production plan, which means that the profits are unbound (Varian, 1992). Also, even in cases wherea profit maximization production plansexists; it may not be unique,which leads to a situation where there is a whole range of production plans that are profit maximizing(Varian, 1992). Using a non-constant returns-to-scale technology helps in resolving thischallenge in case of unbound profit or where a range of production plans exists.

3.2 Empirical Framework

3.2.1 Empirical model

Following Christensen e*t al*. (1971) and assuming that a poultry farmer in Kiambu County aims to maximize profit subject to technological constraints and a mix of fixed inputs, the following normalized restricted translog profit function in a single output setting was specified :

$$ln\pi^* = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln P_i^* + 0.5 \sum_{i=1}^{n} \sum_{h=1}^{n} \gamma_{ih} \ln P_i^* \ln P_h^* + \sum_{i=1}^{n} \sum_{k=1}^{m} \delta_{ik} \ln P_i^* \ln Z_K + \sum_{k=1}^{m} \beta_k \, lnZ_k + 0.5 \sum_{k=1}^{m} \sum_{j=1}^{m} \phi_{kj} \ \ln Z_k \ ln \ Z_j \qquad (3.6)$$

where:

$\boldsymbol{\pi^*}$= the normalized restricted profit (defined as total revenue minus total variable cost divided by the output price).

$\boldsymbol{P_i^*}$= the price of the variable input normalized by $\mathbf{P_y}$, the price of output.

$\boldsymbol{Z_k}$= kth fixed input.

i = *h* = 1, 2, 3..., *n*; *k* = *j* = 1, 2, 3..., *m* (where *n* is the total number of variable inputs and *m* is the total number of fixed inputs),$\boldsymbol{\alpha_o, \alpha_i, \gamma_{ih}, \delta_{ik}, \beta_k}$, and$\boldsymbol{\phi_{kj}}$are the parameters to be estimated.

From equation (3.6), the share of variable expenditure for the *i*th input to restricted profit is given by:

$$\boldsymbol{S_i} = -\frac{P_i^* X_i}{\pi^*} \approx \frac{\partial ln\pi^*}{\partial lnP_i^*} \qquad (3.7)$$

whilethe share of output supply (V) to normalized restricted profit, $\boldsymbol{\pi^*}$is defined as:

$$\boldsymbol{S_v} = \frac{V}{\pi^*} \qquad (3.8)$$

In this case, $\boldsymbol{S_\upsilon}$is also equivalent to the ratio of the total value of output to restricted profit. These ratios are important because they add up to unity. Hence,dropping one of the ratios makes it possible to simultaneously estimate the profit function and the remaining share equation as function of normalized prices and quantities of fixed factors as exogenous variables.

Differentiating equation (3.6) with respect tolnP_i^* and lnP_y respectively gives a system of: (i) variable input shareequations(or the input-profit ratio function), and (ii) output supply function(or the output-profit ratio function) (Diewert 1974; Christensen *et al.*, 1971). However, since input (S_i) and output shares(S_υ) form a singular system of equations, (by definition, $Sv - \sum S_i \ = 1$),the output supply equation (3.8) can be dropped and only the variable input shareequation (3.7) and the translog equation (3.6) used for econometric estimation, such that,

$$S_i = -\frac{P_i^* X_i}{\pi^*} = \frac{\partial ln\pi^*}{\partial lnP_i^*} = \alpha_i + \sum_{h=1}^{n} \gamma_{ih}\, lnP_h^* + \sum_{k=1}^{m} \delta_{ik}\, lnZ_k \qquad (3.9)$$

Profits and variable inputs are estimated simultaneously with normalized input prices and quantities of fixed factors being the exogenous variables. Based on equations (3.6) and (3.9), the elasticities of variable input demand and output supply with respect to all exogenous variablesevaluated at averages of S_i and at given levels of variable input prices (in the case of fixed factors) are linear transformations of parameter estimates of the profit function. Therefore, the variable inputs and output supply elasticities with respect to input prices, output price and fixed inputs can be obtained from the model.

From equation (3.9), therefore, the demand for the *i*th variable input can be written as:

$$\boldsymbol{X_i} = \frac{\pi}{p_i}\left(-\frac{\partial ln\pi}{\partial lnP_i}\right) \qquad (3.10)$$

Taking logs, this translates to:

$$lnX_i = ln\pi - lnP_i + ln\left(-\frac{\partial ln\pi}{\partial lnP_i}\right) \qquad (3.11)$$

The own-price elasticity of demand (η_{ii})for X_i is given by:

$$\eta_{ii} = \frac{\partial lnX_i}{\partial lnP_i} = \frac{\partial ln\pi}{\partial lnP_i} - 1 + \frac{\partial ln}{\partial lnP_i}\left(-\frac{\partial ln\pi}{\partial lnP_i}\right) = -S_i^* - 1 - \frac{\gamma_{ii}}{S_i^*} \qquad (3.12)$$

where, $S_i^*$is the simple average of S_i.

Similarly, the cross-price elasticity of demand for the *i*th input with respect to the price of the *h*th input can be obtained from equation (3.6) as:

$$\eta_{ih} = \frac{\partial lnX_i}{\partial lnP_h} = \frac{\partial ln\pi}{\partial lnP_h} + \frac{\partial ln}{\partial lnP_h}\left(-\frac{\partial ln\pi}{\partial lnP_i}\right) = -S_h^* - \frac{\gamma_{ih}}{S_i^*} \qquad (3.13)$$

The elasticity of demand for the *i*th input (η_{iy}) with respect to output price, P_y, can also be obtained from equation (3.6) as:

$$\eta_{iy} = \frac{\partial lnX_i}{\partial lnP_y} = \frac{\partial ln\pi}{\partial lnP_y} - \frac{\partial lnP_i}{\partial lnP_y} + \frac{\partial ln}{\partial lnP_y}\left(-\frac{\partial ln\pi}{\partial lnP_i}\right) = \sum_{i=1}^{n} S_i^* + 1\sum_{h=1}^{n}\frac{\gamma_{ih}}{S_i^*} \ (3.14)$$

Finally, the elasticity of demand (η_{ik}) for the *i*th input with respect to the *k*th fixed factor Z_k is given by:

$$\eta_{ik} = \sum_{i=1}^{n} \delta_{ik}\, lnP_i + \beta_k \frac{\delta_{ik}}{S_i^*} \ (3.15)$$

3.2.2 Description of variables

Equation 3.6was specified as follows:

$$ln\pi^* = \alpha_0 + \alpha_L \ln P_L^* + \alpha_F \ln P_F^* + \alpha_A \ln P_A^* + 0.5\gamma_{LL} \ln P_L^* \ln P_L^* + +0.5\gamma_{FF} \ln P_F^* \ln P_F^* + 0.5\gamma_{AA} \ln P_A^* \ln P_A^* + \gamma_{LF} \ln P_L^* \ln P_F^* + 0.5\gamma_{LA} \ln P_L^* \ln P_A^* + 0.5\gamma_{FA} \ln P_F^* \ln P_A^* + \delta_{L1} \ln P_L^* \ln Z_1 + \delta_{F1} \ln P_F^* \ln Z_1 + \delta_{A1} \ln P_A^* \ln Z_1 + \delta_{L2} \ln P_L^* \ln Z_2 + \delta_{F2} \ln P_F^* \ln Z_2 + \delta_{A2} \ln P_A^* \ln Z_2 + \beta_1 \ln Z_1 + \beta_2 \ln Z_2 + 0.5\phi_{11} \ln Z_1 \ln Z_1 + 0.5\phi_{22} \ln Z_2 \ln Z_2 + \phi_{12}\ lnZ_1Z_2 \quad (3.16)$$

In equation (3.16), profit (in Kenya shillings) was the endogenous variable. The exogenous variables in the equationwere prices of variable inputs (labour, feed and antibiotics) normalized by the price of output (meat for broilers and eggs for layers), and the fixed inputs (capita equipment, infrastructure and land size).In equation (3.16),the variabes were defined as follows;

π*= the normalized restricted profit (total revenue minus total variable cost divided by the output price)

P*$_L$= the wage rate of labor per day normalized by the price of outputobtained by dividing the total labor expenditurein layer orbroiler production per farm by the quantity of labor including both family and hired labor)

P*$_F$= the price per kilogram of feed normalized by the price of output, and***P****$_A$was the price of a kilogram of the active ingredient of antibiotics used on layers or broiler normalized by the price of output. In this case, only data for farmers who used tetracycline (the most commonly used class of antibiotic in both broiler and layer production systems) were used. The price per kg of tetracycline was computed accordingly.

Z_1=the size of land used for poultry production per farm in hectares

Z_2,= the value of capital equipment and infrastructure invested in poultry production in Kenya shillings per farm.

In layer production, there were three types of feed used at different stages,namely, chick mash, growers' mash and layers' mash,while in broiler production there were two types of feed, such that, broilers' starter and broilers' finisher. These feed types were treated like different inputs in their respective models due to their distinct features in terms of prices, quantities used, as well as their disparate biological effect on the chicken.

The antibiotic demand equation wasobtained by differentiating equation (3.16) with respect to antibiotic price. The antibiotic demand equation was empirically specified as:

$$-\frac{\mathrm{P}^{*}.\mathbf{X_A}}{\pi^{*}} = \alpha_0 + \alpha_{AA}\ln P_A^{*} + \alpha_{AF}\ln P_F^{*} + \alpha_{AL}\ln P_L^{*} + \beta_{A1}\ln Z_1 + \beta_{A2}\ln Z_2 \quad (3.17)$$

where$\boldsymbol{X_A}$was the antibiotic demand while the rest of the variables were as defined earlier.

Table 3.1 presents the description of price variables used in the empirical model given in equation (3.17) as well as their hypothesized signs.

Table 3.1. Description of price variables used in the antibiotic demand equation and their expected effect on antibiotic demand

Variable	Description	Measurement	Expected effect of antibiotic demand
X_A	Quantity of tetracycline used	Kg of active ingredient	None (Dependent variable)
P_A	Tectracycline pricenormalized by output price	Kshs/kg of active ingredient	-
P_F	Feed prices normalized by output price	Kshs/kg of feeds	-
P_L	Wage rate normalized by output price	Kshs/day	-
P_y	Meat or eggs	Kshs/Kg of meat or per egg	+
Z1	Land	Hectare	-
Z2	Capital	Kshs/farm	-

Source: Author

The own-price elasticity for antibiotics which is of major interest in thisstudy was hypothesized to be negatively associated with normalized profit.This is because economic theory postulates that as the prices of an input increases less of the input is demanded (Varian, 1992). According to Bayramoglu and Chakir (2010), output price has a positive effect on damage control input. In this study therefore, the antibiotic demand function was expected to have a positive elasticity with respect to output (chicken meat and egg). Cross-price elasticities of antibiotic demand with respect to other variable inputs (feeds and labor)and fixed inputs (land and capital) were expected to be negative (Pina and Forcada, 2004). The negative sign implies that antibiotics are complements to feeds and labor (Debertin, 1986).

3.2.3 Empirical model estimation procedure

Input share equations (3.9) and profit function equation and (3.6) were estimated jointly because the parameters appearing in the share equations also appear in the profit function. It is also worth noting that after normalizing the profit and input prices by the output price; the output share equation (equation 3.8) was dropped to avoid singularity of the covariance matrix because the profit shares add up to one.The error term for each equation was assumed to be correlated across the equations (Chaudhary *et al.,* 1998).

The profit function and input share equations estimation involve a system of SUR where the correlation of the error terms across equations is assumed. The cross-equation restrictions cannot be imposed in OLS estimation. Use of OLS would yield inefficient parameters as it ignores the correlation of error terms across equations (Greene, 2011). SUR is used instead. It uses a three stage least squares (3SLS) technique which applies feasible generalized least squares (FGLS) estimation. The estimatorgenerated by SUR is asymptotically equivalent to the generalized least squares (GLS) estimator which is unbiased and efficient among the set of maximum likelihood estimators.

FGLS system is sensitive to which equation is dropped to avoid singularity (Greene, 2011). However, iterating on the 3SLS procedure leads to estimates that are asymptotically invariant to the choice of the equation to be dropped. This procedure alsogenerates maximum likelihood estimates of parameters (Greene, 2011).The R-squared statistic computed from the GLS sum of squares need not be bounded between zero and one and does not represent the percentage of total variation in the dependent variable that is accounted for by the model. In STATA software, SUREG command is used to estimate SUR.

In this study, the price elasticity of demand for antibiotics in both layer and broiler production was computed using coefficients of their respective normalized restricted translog profit functions. Elasticities are a function of input shares (S_i), variable input prices (P_i), level of fixed inputs (Z_k) and the parameter estimate of the normalized restricted translog profit function. These elasticities were computed at simple averages of the input shares and at geometric means of the variable input prices and of fixed inputs. The elasticity of antibiotic demand with respect to own price, price of other variable inputs and output price was computed using the formulas shown in equations (3.12), (3.13) and (3.14) respectively.

3.3 Diagnostic tests

3.3.1 Specification and classical tests of the broilers' and layers' SUR

First, a test was conducted to assessthe validity of the assumption that defined the specification of the SUR model. The assumption was that the errors across the profit and share equations are contemporaneously correlatedsuch that, all the errors across the equations are correlated at the same time. In case the assumption did not hold, the SUR estimators would collapse into an OLS estimator. The Breusch-Pagan Test was used where the null hypothesis was that there is no contemporaneous correlation in the model.

A variance inflation factor (VIF) test was undertaken to- assessthe existence of multicollinearity, which just as in OLS, can also be a problem in GLS estimation. Multicollinearityleads to estimators with large variances and covariance, making precise estimation difficult. Consequently, theconfidence intervals tend to be much wider, thereby making the t-values not to be statistically significant when they are, or, in other words, committing type one error (Gujarati, 2008). As a rule of thumb, if the VIF of a variable exceeds 10, that variable is said be highly collinear (Kleinbaum*et al.,* 1988).

Heteroskedasticity was not tested for because FGLS is designed to produce an optimal unbiased estimator of parameters in situations with heterogeneous variance(Gujarati, 2008).

Therefore, FGLS takes heteroskedasticity into account since its assumptions allow for heterogeneous variance within the residuals.

TheR-squared statistic for individual equations computed from GLS sum of squares does not represent the percentage of total variation in the dependent variable that is accounted for by the model. Therefore, an overall R-squared was computed for the broiler and layer models, to testfor the goodness of fit of the models. This involved the useof *r2reg3* command in STATA, a command used to compute the overall R-squared for 3SLS and SUR.

3.3.2Tests for the validity of regularity conditions andappropriateness of translog profit functional form

Homogeneity of the profit function was assumed because normalized profit was used instead of nominal profit. Monotonicity was also assumed since according toFarooq *et al.*,(2001), for the monotonicity condition to hold in a translog specification, the estimated output shares must be positive at all data points,which was the case for the two models.

A formal test was carried out to assess the validity of symmetry and parametric restrictions across the profit and share equations. The null hypothesis for the formal test was that the symmetry condition held, such that, $\gamma_{ih}= \gamma_{hi}$; $\delta_{ik}= \delta_{ki}$ and that the parameters of the share equations equal the corresponding parameters in the profit equation at 5 percent significance level. A global test was also carried in each of the models. This is a joint hypothesis on the validity of imposing restrictions in a model in order tojointly estimate the share and profit equations.An F-test was also undertaken to evaluate the appropriateness of the translog relative to the Cobb-Douglasfunctional form. The null hypothesis was that all γ_{ih}=0, all δ_{ik}=0 and all ϕ_{kj}=0

3.4. Study area

This study was carried out in Kiambu County of Kenya. The economy of Kiambu County is dominated by smallholder agriculture which employs about 75 percent of the population (Okello *et al*., 2010). Some of the major economic activities include livestock production (dairy, sheep, goats, pigs and poultry), crop production (for example, coffee, tea, and horticulture), small and large scale businesses and real estate development. In the 2009 livestock census, Kiambu County had the highest commercial chicken population compared to other counties in the country (RoK, 2010). About 85 percent of the poultry produced in Kiambu County are exotic (Okello *et al*., 2010).

Kiambu County comprises of 10 districts namely, Kiambu East (Kiambaa), Kikuyu, Kiambu West, Lari, Githunguri, Thika East, Thika West, Ruiru, Gatanga and Gatundu. Kikuyu District had the highest chicken population in the County in 2009 with 399,043 commercial chicken followed by Gatundu with 366, 834 (GoK, 2010). Table 3.3 shows the commercial population per district in Kiambu County.

Table 3.2. Commercial chicken population in the 10 districts of Kiambu County

Districts	**Commercial chicken population**
Kikuyu	399,043
Gatundu	366,834
Thika west	191,810
KiambuWest	186,631
Kiambu East	185,126
Ruiru	168,294
Gatanga	144,862
Githunguri	110,202
Thika East	49,439
Lari	29,186

Source: RoK (2010)

It is important to note that by the time the study was carried out, Gatundu District had been divided into two districts, Gatundu North and Gatundu South districts. Lists of commercial chicken farmers from the district agricultural offices in the two districts indicated that most of the commercial poultry farmers were concentrated in Gatundu North District with very few farmers from Gatundu South District. The study, therefore, focused on Kikuyu and Gatundu North districts due to their high population of commercial chicken in Kiambu County. Below is a map showing Kiambu County and the locations in which data was collected.

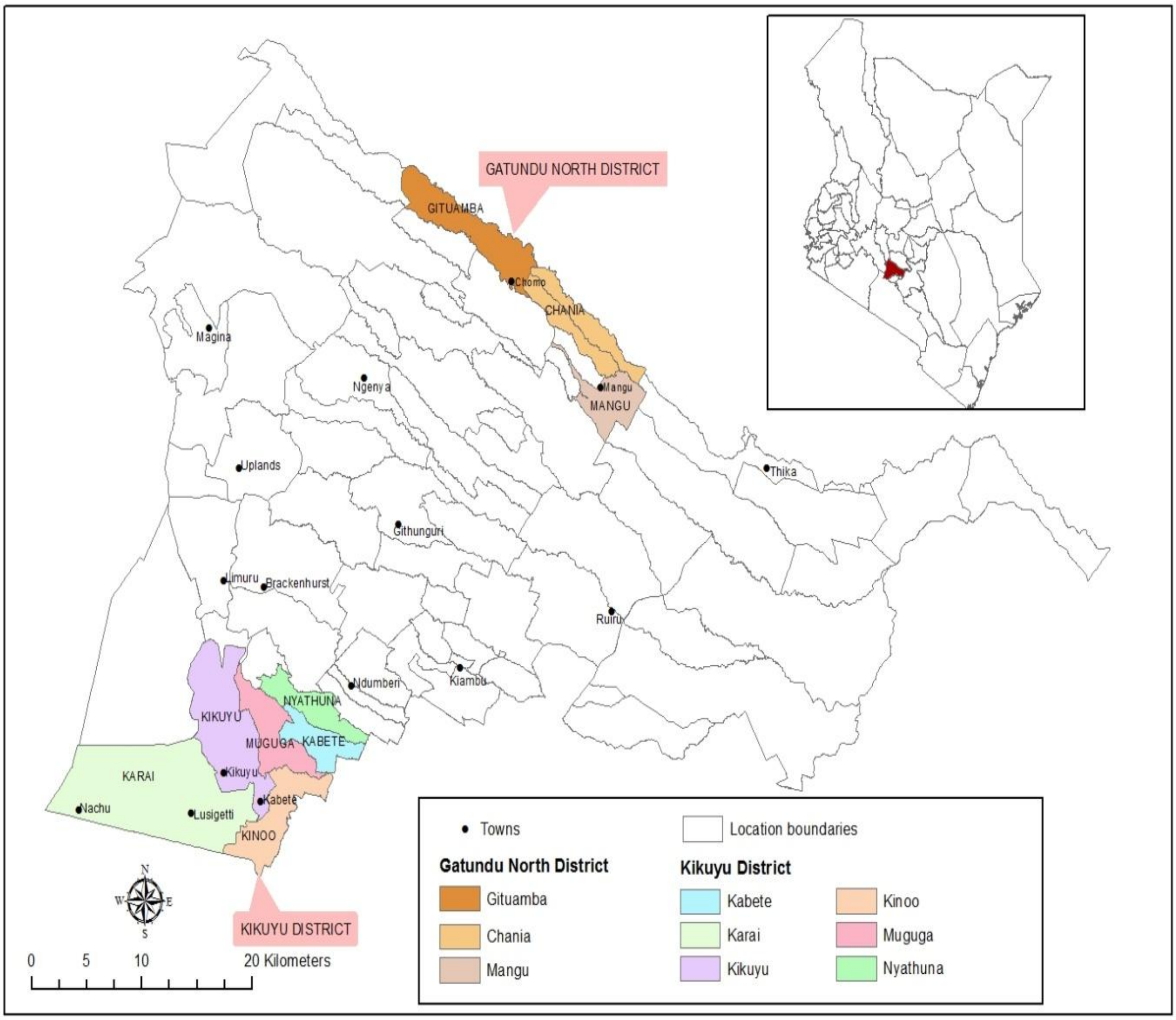

Figure 1 :A map showing the study area and the specific Locations in which the data was collected
Source: ILRI GIS

3.5 Data Sources and sampling procedure

Cross-section primary data were used in this study. The primary data were collected on sampled farms using a semi-structured questionnaire (see Appendix IV). The questionnaire collected data on farmers' information (for example, age, sex, education level, and experience in poultry production), farm characteristics (for example,size of land under poultry and number of chicken kept), poultry production costs and revenues (for example, fixed and variable input costs and output prices), and information on antibiotic use (for example, type of antibiotics used, reason for use, time of use, sources of antibiotics, accessibility of veterinary services and information on antibiotics use).

Two districts in Kiambu County, such that, Kikuyu and Gatundu North districts, were purposively selected because they had the highest poultry population in the County (see Table 3.3). The sampling started at the at the division level because the two districts had very few divisions such that, two divisions in Gatundu North and 4 divisions in Kikuyu Districts.The data were collected following multistage random sample technique, such that, simple random sampling was carried out in stages using smaller and smaller sampling units at each stage. The stages included Locations, sub–Locations, villages and finally households.

The sampling frame of households that kept commercial chicken in each of the selected villages had been constructed by the researcher with the help of village elders. Simple random sampling from the sampling frame was used to select specific households in each of the selected villages;the total number of the households interviewed in each of the selected village was proportion to number of households that kept chicken in each of the village.

Table 3.2 shows the number of Locations, sub-Locations, villages and household that were sampled in the two districts.

Table 3.3.Sampling stages, sampling procedure and sample sizes in Kiambu County

Step	Sampling unit	Sampling procedure	Sample size forKikuyu District	Samplesize forGatundu North District
I	Location	Multistage	6	3
II	Sub-location	Multistage	6	7
III	Village	Multistage	12	7
IV	Household	Simple random	137	101

Source: Author

A sample of 238 commercial farmers was selected in the two districts. This sample was determined by Cochran (1963:75) formula specified as:

$$n = \frac{pqz^2}{E^2}$$

$$n = \left[\frac{(0.5)(0.5)(1.96)^2}{0.0635^2}\right] = 238 \text{ smallholder farmers}$$

where n= sample size, z= confidence level (α=0.05), p= proportion of the population containing the variables of interest, q= 1-p, and E is the allowable (or desired) error because the proportion of the population is not known. In this case, p,q,z and E were assumed to be, 0.5, 0.5, 1.96 and 0.0635 respectively.This resultedin a sample of 238 respondents.

The confidence level (95percent) was based on the Central Limit Theorem, where in a normal distribution, approximately 95 percent of the sample values are within two standard deviations of the true population value (Gujarati, 2008). A proportion of 0.5 (p=0.5) was used because it indicates the maximum variability in a population.It is often used in determining a sample size, such that, the sample size is larger thana sample size wherethe true variability of the population attribute were used which helps to obtain a given level of precision in this case 0.064 (Cochran, 1963).

The questionnaire was administered by enumerators who had been trained by the researcher. The target of the interview was the household head. In cases where the household head was absent or too old to take the interview, a member of the household who was familiar with layer/broiler production was interviewed instead. The layer/broiler production data collected pertained to the last batch already sold. The aim was to obtainthe latest information on antibiotic use in a full layer/broiler production cycle which farmerscould easily recall. The study targeted small scale commercial chicken farmers with 100-1,000 chicken per cyclethis was informed by Nyaga (2007)'s, definition of small scale farmers in poultry production.

3.6 Data analysis

All the questionnaire data were captured in Microsoft Access and analyzed in Statistical Package for Social Sciences (SPSS) version17(for descriptive statistics)and STATA version 11 (for SUR). Descriptive statistics involving the computation of means, independent sample t-tests, and frequencies, were undertaken to characterize the respondents' socio-demographic attributes as well as the antibiotic use patterns in Kiambu County. The results were presented in a tabular form.Thereafter, econometric analysis was undertaken to assess the effect of a unit change in product and factor prices on the demand for antibiotics used in poultry production in Kiambu County by estimating the translog profit equation (3.17) using STATA software.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Characteristics of survey respondents

4.1.1 Distribution of respondents

The poultry farmers were grouped into two production systems, layers andbroilers, in order totake into account of the unique attributes of the two systems with respect to antibiotic use.In Kikuyu District, 72 (or 52.6percent)out of the 137 respondents kept layers while 65 (or 47.4percent) others kept broilers (Table 4.1). Likewise, in Gatundu North District 64 (or 63.4percent) out the 101 respondents kept layers while the other 37percent kept broilers. On overall, 136 (57.1percent) out of 238 respondentsin the sample kept layers while 102 (or 43percent) kept broilers (Table 4.1).

Table 4.1.Distribution of respondents by poultry type and district in Kiambu County

Production system	Kikuyu District		Gatundu North District		Overall	
	n	**Percent**	**n**	**Percent**	**N**	**Percent**
Layer	72	52.6	64	63.4	136	57.1
Broiler	65	47.4	37	36.6	102	42.9
Total	**137**	**100**	**101**	**100**	**238**	**100**

Source: Survey data

4.1.2 Respondents' socio-economic characteristics

Table 4.2shows the main socio-economiccharacteristics of broiler producers. The average age of the household head was 49years(s.e. = 1.32; range =25-72) in KikuyuDistrict and 49 years (s.e. = 1.1; range =29-58) in Gatundu North District.The mean age was notstatistically different in the two districts (p=0.37). The average years of formal education was 11(s.e. = 0.43; range=0-16) and 12(s.e. =0.47; range =0-16) inKikuyu and Gatundu North districts respectively and was not statistically different (p=0.78). On average, farmers in Kikuyu and Gatundu North districts had rearedbroilersfor 9 years (s.e=0.82; range=1-31 for Kikuyu

District and s.e=0.76; range=1-17 for Gatundu North District).The mean years of experience was notstatistically differentin the two districts (p=0.66). The mean household size among respondentsin both Kikuyu and Gatundu North districts was 4 members with s.e=0.16; range=1-7 for Kikuyu District and s.e=0.21; range=3-8 for Gatundu NorthDistrict and was not statistically differentin the two districts (p=5.97).

Table 4.2.Summary of socio-economic characteristics of broiler keepers in Kikuyu and Gatundu North districts of Kiambu County

Characteristic	Kikuyu District n=65		Gatundu North District n= 37		Overall n=102	
	Mean	**Range**	**Mean**	**Range**	**Mean**	**Range**
Age (Years)	49.1 (1.32)	25-72	47.4 (1.11)	29-58	48.5 (0.94)	25-72
Education (Years)	11.4 (0.43)	0-16	11.5 (0.47)	0-16	11.4 (0.32)	0-16
Experience (Years)	9.4 (0.82)	1-31	8.7 (0.76)	1-17	9.2 (0.60)	1-31
Household size (No.)	4.3 (0.16)	1-7	4.4 (0.21)	3-8	4.3 (0.13)	1-8
Area under poultry (ha)	0.005 (0.0005)	0.001-0.03	0.008 (0.003)	0.001-0.1	0.006 (0.01)	0.0004- 0.1
Poultry (No.)	389 (33.1)	100-1000	546 (48.5)	100-1000	446 (28.36)	100-1000

Note: the numbers in brackets are the standard errors of the mean.
Source: Survey data

Table 4.2 also shows the main productive assets owned by farmers who reared broilers. The average area under broiler production was 0.005 (s.e. =0.0005; range =0.001-0.03) and 0.008 (s.e. =0.003; range=0.001-0.1) hectares[2] in Kikuyu and Gatundu North districts respectively. The area was significantly different between the two districts (p=0.098). The average number

[2] 1 hectare= 10,000 square meters

of broilers kept by farmers in Kikuyu District was 349 (s.e. =33; range =100-1000 while in Gatundu North District, farmers kept an average of 500 broilers (s.e. =48; range =100-1000). The two means were statistically different between the two districts (p=0.007).

Table 4.3. Summary of socio-economic characteristics of layer keepers in Kikuyu and Gatundu North districts of Kiambu County

Characteristic	Kikuyu District n=72		Gatundu North District n=64		Overall n=136	
	Mean	**Range**	**Mean**	**Range**	**Mean**	**Range**
Age (Years)	50 (1.38)	28-73	49.7 (1.20)	29-76	49.8 (0.92)	28-76
Education (Years)	9.3 (0.62)	0-18	10.7 (0.54)	0-16	10 (0.42)	0-18
Experience (Years)	13 (0.97)	1-34	9 (0.75)	1-29	11.3 (0.64)	1-34
Household size (No.)	4.6 (0.98)	1-10	4.9 (0.159)	2-9	4.8 (0.13)	1-10
Area under poultry (ha)	0.007 (0.002)	0-001-0.1	0.009 (0.002)	0.001-0.1	0.008 (0.001)	0.001-0.1
Poultry (No.)	349 (24.19)	100-1000	500 (35.12)	100-1000	420 (21.82)	100-1000

Note: the numbers in brackets are the standard errors of the mean.
Source: Survey data

Table 4.3 presents the socio-economic characteristics of layer farmers in Kikuyu and Gatundu North districts. The average age of the household head was50 years (s.e=1.38; range=28-73) in Kikuyu District and 50 years (s.e=1.38; range=29-76) in Gatundu North District. The average age was not statistically different in the two districts (p=0.88).The averageyears of experience were 13 (s.e. =0.97: range=1-34) and 9 (s.e. =0.75; range =1-29) in Kikuyu and Gatundu North districts respectively and were statistically different between the two districts (p=0.002). On the other hand, the average household size was 5 members (s.e. =0.98; range =1-10) in Kikuyu District and 5 members (s.e. =0.16; range =2-9) in Gatundu North District butwas statistically similar (p=0.32). The mean years of formal education was9(s.e. =0.62 range =0-18) in Kikuyu District and 11(s.e. =0.54; range =0-16) in Gatundu North District, which however was notstatistically differentin the two districts (p=0.11).

The main productive assets owned by farmers who reared layers are also shown in Table 4.3. The mean area allocated to layers was 0.007 (s.e. =0.002; range =0.001-0.1) and 0.009 (s.e. =0.002; range =0.001-0.1) hectares for Kikuyu and Gatundu North districts respectively (Table4.3). These means were however not statistically different between the two districts (p=0.499). On average, farmers in Kikuyu District kept 389 layers (s.e. =24.2: range =100-1000) while in those Gatundu North District kept 546 layers (s.e. =35.1: range =100-1000). The average number of layers kept in the two districts was statistically different (p=0.000).

4.1.3 Discussion

The mean age for broiler and layer farmers (49years for broilers and 50 years for layers) were almost similar to Ochieng *et al.*,(2013) studywhich reported a mean age of 43 years poultry farmers in western Kenya.On the other hand, the average number of years of formal education in the overall layer and broiler production systems in the two districts was 10 and 11 respectively. This closelytallied with the finding of Irungu’s(2011) study that reported amean of 13 yearsof formal education for both broilers and layer farmers. Basic education is important particularly in commercial poultry production because many activities such as brooding, treatment and feeding require skills and knowledge that only come through education. Additionally, more educated farmers have been shown to exhibit a lower propensity to misuse veterinary drugs because formal education enables them to read and understand instructions provided on drug labels or package inserts (Irungu *et al*., 2007).

The average years of experience among layer farmers in Kikuyu Districtwas higher than that of farmers in Gatundu North District. This could be because commercial layer farming started earlier in Kikuyu District owing to its proximity to Muguku Farm hatchery, a major source of DOC, and also due to the ease of access to rural (for example, the Wangige egg market) and urban markets(Okello *et al.,* 2010). Additionally, the fact that 57 percent of all 238 respondents kept layers compared to 43 percentwho kept broilers impliesthat layer production is much more widespread than broiler production in Kiambu County as also reported by Okello*et al.*(2010).

4.2 Pattern of antibiotic usein poultry production in Kiambu County

4.2.1 Types and classes of antibiotics used in broiler production

Table 4.4presents the frequency of responses given by respondents who reported using different types of antibioticsin broiler productionin the two study districts. In Kikuyu District, skazon was the most commonly used antibiotic accounting for 23percent of all responseswhile in Gatundu North District, skazon and OTC dawa were the most commonly used antibioticsas mentioned in 16.9percent of the responses.

On overall, skazon was the most commonly used antibiotic in broiler production followed by OTC dawa and agracox accounting for 23, 19 and 9 percent of the responses respectively (Table 4.4).Biotrim accounted for nine percent of the responses with alamycin and tetracycline accounting for six recent of the responses. Limoxin and multiflox antibiotics accounted for four percent of the responses while hiprarona, medicox, amidiostat and tyradoxin accounted for three percent of the responses. The other minor types of antibiotics used in broiler production, includedaliseryl, vetacox, neoxyvita flouquin miramed doxin and vetoxy;they accounted for less than two percent of the responseseach as indicated in Table 4.4.

Table 4.4.Frequency of responses on use of different types of antibiotics in broiler production in Kikuyu and Gatundu North districts of Kiambu County

Type of antibiotic	Kikuyu District		Gatundu North District		Overall	
	n	Percent	n	Percent	n	Percent
Skazon	22	27.5	10	16.9	32	23
OTC dawa	16	20	10	16.9	26	18.7
Agracox	5	6.2	8	13.6	13	9.4
Biotrim	6	7.5	6	10.2	12	8.6
Alamycin	7	8.8	1	1.7	8	5.8
Tetracycline	5	6.2	3	5.1	8	5.8
Limoxin	2	2.5	3	5.1	5	3.6
Multiflox	0	0	5	8.5	5	3.6
Hiprarona	2	2.5	2	3.4	4	2.9
Medicox	2	2.5	2	3.4	4	2.9
Amidiostat	0	0	4	6.8	4	2.9
Tyrodoxin	3	3.8	1	1.7	4	2.9
ESB3	3	3.8	0	0	3	2.2
Aliseryl	1	1.2	1	1.7	2	1.4
Vetacox	2	2.5	0	0	2	1.4
Neoxy vita	2	2.5	0	0	2	1.4
Fluquin	0	0	2	3.4	2	1.4
Miramed	1	1.2	0	0	1	0.7
Doxin	0	0	1	1.7	1	0.7
Vetoxy	1	1.2	0	0	1	0.7
Total	**80**	**100**	**59**	**100**	**139**	**100**

Note: The total *n* in this table is the total number ofresponses,not the number of respondents.
Source: Survey Data

In layer production,biotrim accounted for 17 and 20 percent of the responses in Kikuyu and Gatundu North districts respectively (Table 4.5).Overall,biotrim was the commonly used antibiotic type in layer production accounting for 19 percent of the responses followed by skazon and OTC dawa which accounted 16 and 14 percent of the responses respectively.Agracox and alymacin constituted 10 and nine percent of the responses respectively followed by hiprarona, tetracycline and ESB3 which constituted five, and four (for tetracycline and ESB3) percent respectively. Results indicated that medicox, tyradoxin, miramed, amidiostat and fluquin constituted two percent of the responses each. Doxin, aliseryl, neoxvita, limoxin, anticox,quinol, egocin, vetacox, and sulfatrim were the least used antibiotics in layer production, constituting one percent of the responses each (Table 4.5).

Table 4.5.Frequency of responses on use of different types of antibiotics in layer production in Kikuyu and Gatundu North districts of Kiambu County

Type of antibiotic	Kikuyu District		Gatundu North District		Overall	
	n	**Percent**	**n**	**Percent**	**n**	**Percent**
Biotrim	18	17.3	21	20.2	39	18.8
Skazon	14	13.5	20	19.2	34	16.3
OTC dawa	17	16.3	14	13.5	31	14.9
Agracox	9	8.7	11	10.6	20	9.6
Alamycin	13	12.5	5	4.8	18	8.7
Hiprarona	2	1.9	8	7.7	10	4.8
Tetracycline	6	5.8	3	2.9	9	4.3
ESB3	7	6.7	1	1	8	3.8
Medicox	1	1	4	3.8	5	2.4
Tyrodoxin	1	1	4	3.8	5	2.4
Miramed	3	2.9	1	1	4	1.9
Amidiostat	4	3.8	0	0	4	1.9
Fluquin	0	0	4	3.8	4	1.9
Doxin	0	0	3	2.9	3	1.4
Aliseryl	2	1.9	1	1	3	1.4
Neoxy vita	3	2.9	0	0	3	1.4
Limoxin	0	0	2	1.9	2	1
Anticox	1	1	1	1	2	1
Quinol enrofloxacin	1	1	0	0	1	0.5
Egocin	0	0	1	1	1	0.5
Vetacox	1	1	0	0	1	0.5
Sulfatrim	1	1	0	0	1	0.5
Total	**104**	**100**	**104**	**100**	**208**	**100**

Note: The *n* in this table is the total numbers responses givenby layer producers (not the number of respondents since some respondents used more than one type of antibiotics.
Source: Survey data

All the antibiotics shown in Tables 4.4 and 4.5were grouped into four classes[3]depending on the major active ingredient contained in each antibioticnamely, tetracyclines, sulphonamides, quinolones and nitrofurans.In broiler production, the most commonly used class of antibiotic in the two districts was tetracyclines, which accountedfor 73percent and 51 percent of all the responses in Kikuyu and Gatundu North districts respectively (Table 4.6).Overall, in broiler production, tetracycline was the most commonly used antibiotic class as mentioned by 64 percent of the responses, followed by sulfonamides and quinolones which constituted 25 and 8 percent of the responses respectively. Nitrofuran was the least used class in broiler production constituting only three percent of the responses.

In layer production, tetracyclines were the most used class of antibiotics in the two districts (Table 4.6) where they accounted for 54 percent and 51 percent of the responses in Kikuyu Gatundu North districts respectively. Overall, tetracycline constituted 52 percent of the responses, followed by sulfanomides and quinolones which constituted 35 and 7 percent of the responses. Nitrofuran was the least used class in layer production constituting a mere two percent of the responses.

[3] The classification was based on the active ingredient indicated on the label inserts and also with help of a veterinary surgeon.

Table 4.6.Frequency of responses on different classes of antibiotics used in broiler and layer production in Kikuyu and Gatundu North districts of Kiambu County

Class of antibiotics	Broilers			Layers		
	Kikuyu District	Gatundu North District	Overall	Kikuyu District	Gatundu North District	Overall
	n	n	n	n		n
Tetracyclines	59 (73.8)	30 (50.8)	89 (64)	56 (53.8)	53 (51)	109 (52.4)
Sulfonamides	19 (23.8)	16 (27.1)	35 (25.2)	41 (39.4)	39 (37.5)	80 (38.5)
Quinolones	2 (2.5)	9 (15.3)	11 (7.9)	3 (2.9)	11 (10.6)	14 (6.7)
Nitrofurans	0	4 (6.8)	4 (2.9)	4 (3.8)	1 (1)	5 (2.4)
Total	**80**	**59**	**139**	**104**	**104**	**208**

Note: The *n* in this table is the total numbers responses givenbypoultryproducers (not the number of respondents) since some respondents used more than one type of antibiotics.The numbers in brackets are percentages of total *n*.

Source: Survey data

4.2.2 Antibiotics use practices among poultry farmers

Table 4.7presents the proportion of poultry producers who administered antibiotics to chickens at different growth stages. In broiler production, most of the respondents, 88percent in Kikuyu and 81 percent Gatundu North districts, administered antibiotics between the first and third week.Likewise, in layer production, 57 percent of respondents in Kikuyu District and 56 percent of respondents in Gatundu North District administered antibiotics between first and third week (Table 4.7). The administration of antibiotics however extended after the nineteenth week for among producers.

The long period of antibiotics administration could be because one batch of layers could be kept for about one and a half years hence increasing chances of contracting diseases.It is however important noting that the proportion of respondents who administered antibiotics after the third week in layers and broilers reduced considerably in the two districts. This could be explained by the fact that antibiotics application is useful when done early to serve as an antimicrobial prophylactic (Apata, 2009).

Table 4.7.Proportion of broiler and layer producers who administered antibiotics at differentgrowth stages in Kikuyu and Gatundu North districts of Kiambu County

Growth stage	Broilers			Layers		
	Kikuyu District	Gatundu North District	Overall	Kikuyu District	Gatundu North District	Overall
	n	n	n	n	n	n
1-3 weeks	57 (87.5)	30 (81.4)	87 (84.9)	42 (56.7)	32 (55.8)	74 (56.2)
4-6 weeks	8 (12.4)	7 (18.6)	15 (15.1)	6 (7.7)	8 (13.5)	14 (10.6)
7-9 weeks	0	0	0	4 (5.8)	5 (8.7)	9 (7.2)
10 -12 weeks	0	0	0	11 (14.4)	8 (13.5)	19 (13.9)
13-18 weeks	0	0	0	1 (1.0)	2 (3.8)	3 (2.4)
19 and above weeks	0	0	0	11 (14.4)	3 (4.8)	14 (9.6)
Total	**65**	**37**	**102**	**74**	**62**	**136**

Note: The numbers in brackets are percentages of total *n*.

Source: Survey data

Most farmers (98percent) in broiler productionadministered antibiotics without the help of a qualified veterinary surgeon. In Kikuyu District, 55 percentof the respondents indicated thatthe household head was responsible for antibiotic administration while 26 and 6percent was done by the spousesand farm workers respectively (Table 4.8).Three percentof the respondents reported that the administration was done by a veterinary surgeon in Kikuyu District while only 5 and 2 percent indicatedthat the administration was done byson and daughter respectively. In Gatundu NorthDistrict, 76 percentof the respondentsreported that the household head was responsible for theadministration while 19 percent indicated that it was done by the spouses. Six percent of the respondent indicated that the administration was done by a farm worker while no respondent reported administration of antibiotics by a veterinarian in Gatundu North District.

In the layer production, most respondents in the two districts(60 percent in Kikuyu and 73 percent in Gatundu North districts respectively), indicated that the household head was responsible for administering antibiotics (Table4.8). Six percent of the respondents in the two districts indicated that the administration was done by the farm workers while one and two percent was done by the daughters and the same percentage for the sons in Kikuyu and Gatundu North districts respectively.Only one farmer from Kikuyu District had a veterinary surgeon administer the antibiotics in layer production as shown in Table 4.8.

Table 4.8.Frequency of respondents who administered antibiotics to broilers and layers in Kikuyu and Gatundu North districts of Kiambu County

Antibiotics administrator	Broilers			Layers		
	Kikuyu District	Gatundu North District	Overall	Kikuyu District	Gatundu North District	Overall
	n	n	n	n	n	n
Household head	36 (55.4)	28 (75.7)	64 (62.7)	43 (59.7)	47 (73.4)	90 (66.2)
Spouse	17 (26.2)	7 (18.9)	24 (23.5)	22 (30.6)	11 (17.2)	33 (24.3)
Son	3 (4.6)	0	3 (2.9)	1 (1.4)	1 (1.6)	2 (1.5)
Daughter	1 (1.5)	0	1 (1)	1 (1.4)	1 (1.6)	2 (1.5)
Farmworker	6 (9.2)	2 (5.4)	8 (7.8)	4 (5.6)	4 (6.2)	8 (5.9)
Vet doctor	2 (3.1)	0	2 (2)	1 (1.4)	0	1 (0.7)
Total	**65**	**37**	**102**	**72**	**64**	**136**

Note: The numbers in brackets are percentages of total *n*.

Source: Survey data

Only20percent of all the broiler andlayer farmers in the two districts kept drug records (Table 4.9).Record keeping is necessary because it keeps track of all the drugs used on the poultry. This information is important on informing veterinary surgeonsattending the poultry on the necessary drugsand their right dosages that should be recommended in a given case. The low frequencies of record keeping may create a potential for drug misuse through over-/under-dosing which increases the risk of development of antibiotic resistance.

Table 4.9.Proportion of broiler and layer farmers who kept drug recordsin Kikuyu and Gatundu North districts of Kiambu County

Record keeping	Broilers			Layers		
	Kikuyu District	Gatundu North District	Overall	Kikuyu District	Gatundu North District	Overall
	n	n	n	n	n	n
Yes	13	7	20	16	25	41
	(20)	(20)	(20)	(20)	(20)	(20)
No	52	28	80	56	39	95
	(80)	(80)	(80)	(80)	(80)	(80)
Total	**65**	**35**	**100**	**72**	**64**	**136**

Note: The numbers in brackets are percentages of total *n*.

Source: Survey data

4.2.3 Sources of information on antibiotic sources and use

About 75 percentof broiler farmers in Kikuyu District and 51 percent in Gatundu North District did not have any kind of training on antibiotic use (Table 4.10).In layer production, 26 percent and 25 percent of the respondents had training on antibiotic use in Kikuyu and Gatundu North districts respectively. Training farmers on antibiotic use, the effect of antibiotic misuse and also on ways of practicing less antibiotic intensive practices such as using different sanitation and hygiene measures to control poultry diseases as a substitute to using antibiotics would be an important way of reducing antibiotic use.

Table 4.10.Proportion of broiler and layer farmers who had trainingon antibiotic use in Kikuyu and Gatundu North districts of Kiambu County

Training	Broilers			Layers		
	Kikuyu District	Gatundu North District	Overall	Kikuyu District	Gatundu North District	Overall
	n	n	n	n	n	n
Trained	16 (24.6)	19 (51.4)	35 (34.3)	19 (26.4)	16 (25)	35 (25.7)
Not trained	49 (75.4)	18 (48.6)	67 (65.7)	53 (73.6)	48 (75)	101 (74.3)
Total	**65**	**37**	**102**	**72**	**64**	**136**

Note: The numbers in brackets are percentages of total *n*.

Source: Survey data

Among the broiler farmers who had training in antibiotic use, 71 percent had attended seminars, while 28 and 3 percent had been to either training forums or workshops respectively (Table 4.11). In layer production, of all the farmers who had training, 91 percent had attended seminars while nine percent had attended training forums.

Table 4.11.Proportion of broiler and layer farmers who attended different trainings in Kikuyu and Gatundu North districts of Kiambu County

Kind of training	Broilers			Layers		
	Kikuyu District	Gatundu North District	Overall	Kikuyu District	Gatundu North District	Overall
	n	n	n	n	n	n
Seminars	11 (68.8)	14 (73.7)	23 (71.4)	17 (89.5)	15 (93.8)	32 (91.4)
Training forum	4 (25)	5 (26.3)	9 (27.7)	2 (10.5)	1 (6.2)	3 (8.6)
Workshops	1 (6.3)	0	1 (2.9)	0	0	0
Total	**16**	**19**	**35**	**19**	**16**	**35**

Note: The numbers in brackets are percentages of total *n*.

Source: Survey data

Table 4.12 shows the sources of information on antibiotic use among broiler and layer farmers in the two study districts. The most commonly used information source among broiler farmers was an agro-vet operator with45 percent of farmers in Kikuyu and 50 percent in Gatundu North districts usingit respectively.Other farmers used either their past experience (33 percent), read instructions on drug label inserts (20 percent) or consulted their neighbours or friends (3 percent).Likewise, in layer production, most of the farmers in the two districts who did not have any kind of training, acquired knowledge on antibiotic use by consulting an agro-vet (68 and 63 percent in Kikuyu and Gatundu North districts respectively) (Table 4.12).Some of the other ways included using past experience (23 percent) or reading instructions on the labels (12 percent).

The levels of consulting were fairly high (46 percent for broilers and 65 percent for layers on overall). However, the farmers consulted agro-vet operators who according to GARP, (2011) are mostly untrained and/or do not have professional qualifications. Consulting professionals on antibiotic use is an important way of obtaining accurate drug use information, which enhances the correct and safe use of antibiotics at the farm level.

Table 4.12.Frequency of respondents who used various sources of information on antibiotic usein broiler and layer production in Kikuyu and Gatundu North districts of Kiambu County

Source of information on antibiotic use	Broilers			Layers		
	Kikuyu District	Gatundu North District	Overall	Kikuyu District	Gatundu North District	Overall
	n	n	n	n	n	n
Consulting vet doctor /Agro vet	22 (44.9)	9 (50)	31 (46.3)	36 (67.9)	30 (62.5)	66 (65.3)
Past experience	17 (34.7)	5 (27.8)	22 (32.8)	13 (24.5)	10 (20.8)	23 (22.8)
Reading instructions on labels	9 (18.4)	3 (16.7)	12 (17.9)	4 (7.5)	8 (16.7)	12 (11.9)
Consulting from friends	1 (2)	1 (5.6)	2 (3)	0	0	0
Total	**49**	**18**	**67**	**53**	**48**	**101**

Note: The numbers in brackets are percentages of total *n*.

Source: Survey data

Over 80 percentof farmers in Kikuyu District and 90 percent in Gatundu North District bought antibiotics from agro-vet shops (Table 4.13). A few other broiler farmers bought antibiotics from individual veterinarians (11 percent), animal health assistants (2 percent) or contractors[4] (1 percent).All of the respondents who kept layers in Gatundu North District bought their antibiotics from agro-vet shops. In Kikuyu District, more than 80 percent bought their antibiotics from agro-vet shops while the rest bought from either individual veterinarians (6 percent) or animal health assistants (2 percent).

[4]Some farmers in Kiambu County produced poultry on contract with poultry product manufacturers, consequently, some contractors supplied veterinary inputs to farmers.

Table 4.13.Frequency of broiler and layer farmers who acquired antibiotics from various sources in Kikuyu and Gatundu North districts of Kiambu County

Source of antibiotics	Broilers			Layers		
	Kikuyu District	Gatundu North District	Overall	Kikuyu District	Gatundu North District	Overall
	n	n	n	n	n	n
Agro-vet shop	58 (89.2)	36 (97.3)	94 (92.2)	61 (84.7)	64 (100)	125 (91.9)
Individual veterinarian	4 (6.2)	1 (2.7)	5 (4.9)	8 (11.1)	0	8 (5.9)
Animal heath assistant	2 (3.1)	0	2 (2.0)	3 (4.2)	0	3 (2.2)
Supplied by contractor	1 (1.5)	0	1 (1)	0	0	0
Total	**65**	**37**	**102**	**72**	**64**	**136**

Note: The numbers in brackets are percentages of the total *n*.

Source: Survey Data

4.2.4 Access to markets and veterinary services

Broiler farmers in Kikuyu Districtwere on average, 2.1km (s.e. =0.27, range =0.5-12) away from an agro-vet outlet while those in Gatundu North District were 6.1 km away(s.e. =0.77; range =0.5-20) (Table 4.14). On the other hand, broiler farmers in Kikuyu and Gatundu North districts were, respectively, 2.7km(s.e. =0.35; range=0.1-12) and 6.4 km (s.e. =0.86; range=0.1-20) away from a veterinary doctor on average. Likewise, the mean distance to ananimal health assistant was 2.2km (s.e. =0.35; range=0.5-12) in Kikuyu and 6.2km(s.e. =0.79; range=0.02-20) in Gatundu North districts. The longest distance was that between farmer's homestead and primary outlet for poultry products which,on average,was 6km(s.e. =1; range=1-43) and 22.9 km (s.e. =3.2; range=4-60) away in Kikuyu in Gatundu North districts respectively. All the distances were statisticallydifferent between the two districts ($p<0.05$) (Table 4.14).

Table 4.14.Mean distances from farmers' homesteads to markets and sources of veterinary services for broiler farmers in Kikuyu and Gatundu North districts of Kiambu County

Distance of homestead to (km)	Kikuyu District			Gatundu North District			Overall		
	n	**Mean**	**Range**	**n**	**Mean**	**Range**	**n**	**Mean**	**range**
Agro vet	65	2.1 (0.27)	0.5-12	37	6.1 (0.77)	0.5-20	102	3.6 (0.38)	0.5-20
Animal health assistant	55	2.2 (0.35)	0.5-12	37	6.2 (0.79	0.02-20	92	3.8 (0.43)	0.02-20
Veterinary doctor	61	2.7 (0.35)	0.1-12	35	6.4 (0.86)	0.5-20	96	4.1 (0.41)	0.1-20
Shopping centre	65	1.3 (0.1)	0.5-4	37	4.8 (0.80)	0.25-20	102	2.6 (0.34)	0.25-20
Market	65	4 (0.47)	0.5-17	37	10.6 (2.11)	4-60	102	6.2 (0.88)	0.5-60
Major town	65	4 (0.5)	0.25-17	37	16 (2.21)	4-60	102	8.7 (1.03)	0.25-60
Primary poultry product outlet	59	6 (1.0)	1-43	37	22.9 (3.16)	4-60	92	12.5 (1.6)	1-60

Note: The numbers in brackets are standard errors of the mean
Source: Survey data

Table 4.15shows the mean distances to market and veterinary services for the farmers who kept layers. The mean distance to an agro-vet operator was 2.2km (s.e. =0.3; range=0.2-15) in Kikuyu District and 5.3 km (s.e. =0.5; range=0.13-16) in Gatundu North District. Farmers in Kikuyu District were on average 2 km (s.e. =0.3; range=0.02-16) away from an animal assistant while those in Gatundu North District were on average 6.1 kilometres (s.e. =0.36; range=0.01-16) away. On average, the distance to a veterinary surgeon was 2.1km (s.e. =0.19; range=0.25-8) and 5.3km (s.e. =0.28; range=0.01-16) for Kikuyu and Gatundu North farmers respectively. The mean distance to the primary outlet was 4.6 km (s.e. =0.73; range=0.2-35) among farmers in Kikuyu and 10.7 km (s.e. =0.71; range=0.1-35) for those in

Gatundu North districts. Like in the case of broilers (see Table4.14), the mean distances were all statistically different between the two districts ($p<0.05$).

Table 4.15.Mean distances fromfarmers' homesteads to markets and sources of veterinary services for layerfarmers in Kikuyu and Gatundu North districts of Kiambu County

Distance of homestead to (km)	Kikuyu District			Gatundu North District			Overall		
	n	**Mean**	**Range**	**n**	**Mean**	**Range**	**n**	**Mean**	**Range**
Agro vet	72	2.2 (0.3)	0.2-15	64	5.3 (0.47)	0.12-16	136	3.6 (0.3)	0.12-16
Animal health assistant	57	2 (0.3)	0.01-16	50	6.1 (0.54)	0.2-16	107	3.9 (0.36)	0.01-16
Veterinary doctor	69	2.1 (0.19)	0.25-8	64	5.3 (0.47)	0.01-16	133	3.7 (0.28)	0.01-16
Shopping centre	72	1.4 (0.1)	0.02-5	64	4 (0.51)	0.01-16	136	2.6 (0.27)	0.01-16
Market	72	4.9 (0.52)	0.25-20	64	6.7 (0.69)	1.2-25	136	5.8 (0.43)	0.25-25
Major town	72	5.5 (0.58)	0.5-30	64	11 (0.95)	2-35	136	8.1 (0.59)	0.5-35
Primary poultry product outlet	71	4.6 (0.73)	0.2-35	64	10.7 (1.15)	0.1-35	123	7.4 (0.71)	0.1-35

Note: Numbers in brackets are the standard errors of the mean.
Source: Survey data

4.2.5 Discussion

Veterinary drug use affords higher animal productivity if well applied. This study found widespread use of antibiotics among poultry farmersin Kikuyu and Gatundu North districts. Tetracyclines were the most commonly used antibioticsin both broiler and layer production in the two districts followed by sulfanomides, quinolones and nitrofurans. This was almost similar to the finding of Eagar *et al.* (2012) where teracyclines and sufanomides were ranked second and third respectively in livestock use after pleuromutilins in South Africa. Mitema *et* *al.* (2001) also explained that tetracyclineswas the most popular antibiotic class in Kenya followed by sulfanomides while the rest of the classes included quinolones, macrolides and beta lactams. This popularity was attributed to the high preference for tetracyclinesamong veterinarians and producersbecause of its broad-spectrum antibacterial activity and affordability.

Mostof the respondents surveyed in this study administered antibiotics in the early growth stages of the chicken as a disease preventive measureto avoid losses. Most of the antibiotics were however administered without the help of a professional. In fact, only two percentof broiler producers and 0.7 of layer producersconsulted a veterinary surgeon in drug administration.This could be because, with time, poultry farmers learn the routine administration of antibiotics from veterinarians and dispense with them thereafter to minimize costs. Additionally, more than 90 percent of the farmers bought antibiotics from agro-vet shops. This was probably due to their proximity and also the fact that in agro-vet shops they bought the drugs over the counter unlike in other sources where they also needed to pay for consultation services.

On the other hand, most of thefarmers who administered antibiotics (74 percent and 66 percent of all layer and broiler farmersrespectively) did not have any kind of training on antibiotic use. Most of these farmers (65 percent and 46 percent of layer and broiler farmers respectively) consulted agro-vet operators where they bought the antibiotics while the rest either relied on past experience or reading instructions on drug labels.Thesefindings tallywith those reported by GARP (2011) wheremost of livestock producers were found to administer antibiotics without professional help.Additionally, most of the farmers (80 percent in the two production systems) did not keep any drug records. This was also the case in Irungu(2011) who observed that most of the farmers (89 percent) did not keep any drug records.These practices create the potential for drug misuse through over-/under-dosing,which increases the risk of development of antibiotic resistance.

Veterinary services in the two districts were readily accessible with agro-vets being, on average, less than 4 kmaway from farmers' homesteads in both production systems. Veterinary surgeons and animal health assistants were also, on average,about 4 km away. This was however different from the case of indigenous poultry production in western Kenya where Ochieng *et al.*,(2013) found that veterinary services were only accessed by less than half of survey farmers, distance was said to be one of the factors contributing to the lack of access of veterinary services in the study area.

Given theresults of the current study, lack of professionalism could therefore, not be attributed to lack of access of veterinary services for layers and broilers in Kiambu County. Veterinary service providers can be of good use in promoting professionalism in antibiotic use on poultry production because they are easily accessible by poultry farmers. The problem is that most farmers neither had any training nor did they seek professional help during antibiotic purchase and administration, which poses a potential risk of drug misuse and there elevates the likelihood of development of antibiotic resisitance

4.3. Results for diagnostic tests

4.3.1 Specification test

The computed chi-square from the Breusch-Pagan Test for the broiler SUR was 105.4 (p=0.000). In the layer SUR, the computed chi-square was 200.0 (p=0.000). Therefore, the null hypothesis,that the errors across the profit and share equations are contemporaneously correlated, was rejected in the two models implying that the assumption of error correlation across the profit and share equations held.

4.3.2 Goodness-of-fit

The computed overall adjusted R-squared was 0.70 and 0.62 in the broiler and layer model respectively, indicating that the two models fitted the data well (Greene, 2011).

4.3.3 Multicollinearity

In Table 1.16, the results showed that all variables in the layer model had a VIF <2. Based on the rule of thumb, that, if the VIF of a variable exceeds 10, that variable is said be highly collinear, there was no evidence of multicollinearity amongst independent variables.

Table 4.16Results for VIF test for the layers' model

Variable	**VIF**	**1/VIF**
Ln chick mash	1.66	0.6022
Ln layer mash	1.53	0.6530
Ln land	1.13	0.8846
Ln antibiotics	1.13	0.8863
Ln growers mash	1.11	0.8993
Ln labour	1.06	0.9445
Ln capital	1.04	0.9598
Mean VIF 1.24		

Source: Survey data

However, in broiler model, prices of the broiler starter feeds and broiler finisher feeds had a VIF of 12 and 12.5 respectively which meant there was evidence of multicollinearity between the two variables. Consequently, the price of broiler starter feeds was dropped and after the

VIF test, the model had a VIF <2, (Table 4.17). Therefore, the broiler model was estimated without the broiler starter price.

Table 4.17Results for VIF test for the broilers' model

Variable	**VIF**	**1/VIF**
Ln labour	1.10	0.9091
Ln capita	1.08	0.9252
Ln land	1.08	0.9288
Ln antibiotics	1.05	0.9542
Ln broilers finisher	1.03	0.9726
Mean VIF 1.07		

Source: Survey data

4.3.4 Appropriateness of translog profit functional form

The computed $F_{(10, 241)}$ for the broiler profit function was 2.23 (p=0.027), thereby rejecting the null hypothesis, that all γ_{ih}=0, all δ_{ik}=0 and all ϕ_{kj}=0,at 5 percent significance level. On the other hand, the computed $F_{(21,392)}$ for the layer profit function was 2.16 (p=0.028), in which case the null hypothesis was rejected at 5 percent significance level. This implied that the conditions for a Cobb-Douglas did not hold; the translog functional form was therefore deemed more suitable than the Cobb-Douglas for use in estimating the profit equation.

4.3.5 Validity of symmetry and parametric restrictions

In the broiler model, 18 symmetrical and parametric restrictions were imposed. Individual tests indicated that for all the 18 restrictions, the null hypothesis that, symmetry condition andthe parameters of the share equations equal the corresponding parameters in the profit equation, held could not be rejected (P>0.005). This meant that the symmetry and parametric conditions held in all cases (see Appendix I). The global test was also conducted to test the joint hypothesis on the validity of imposing the 18 restrictions to estimate jointly the share equations and the profit equation using an F test. The computed $F_{(18,\ 241)}$[5] was 1.03 (p = 0.423) meaning, the null hypothesis that the symmetry and parametric conditions held jointly, could not be rejected at 5 percent significance level. The implication of this finding was that all the 18 restrictions in the profit equation and the share equations for broilers held. The result for the broiler model therefore implied that among other things, the sample farms, on average, maximized profit given the normalized prices of fixed and variable inputs.

In the layer model, 40 symmetrical and parametric restrictions were imposed. Results from individual restrictions tests indicated that, at 5 percent significance level, 10 out of 40 restrictions did not hold; such that, the null hypothesis that the symmetry and parametric conditions held, was rejected (Appendix II). A global F test was also carried out. The computed $F_{(40,\ 392)}$ was 3.43 (p= 0.000), meaning that the null hypothesis was rejected at 5 percent level of significance. This meant that not all the symmetry conditions held in the profit and share equations for layers, which implied that the results were not entirely consistent with the maintained hypothesis of symmetry and therefore, demand equations may not fully reveal the input requirements if the producer does not maximize profits.

To ascertain whether this was the case, the 10 restrictions that did not hold in the layer model were dropped and a global test done. The resultant computed $F_{(30,392)}$ was 1.34 (p= 0.1097); implying that the null hypothesis could not be rejected. This implied that the symmetry conditions held and therefore the 10 restrictions were inaccurate and would not serve as a maintained hypothesis. A system of profit and variable inputs share equations were then re-estimated without imposing the 10 restrictions (Appendix III). The resulting parameters were

[5]Note:The numerator degrees of freedom (df) in the joint F-test were the number of restrictions. The denominator df, (usually given by ***n*-k**) were greater than ***n*** (farmers who used tetracycline, 78 for layers and 70 for broilers model) because each model had more than one equation and therefore ***n*** was multiplied by the number of equations then less the number of all the parameters in all the equations E.g. in broiler model which had 4 equations with a total of 39 parameters (**k**=39) and ***n***=70 denominator df was given by (70*4)-39=241.

compared to the parameters of the layer model with all (40) restrictions imposed using Akaike Information Criterion (AIC). The result showed the layer model estimated with all the 40 restrictions was 1.7 times as probable as the layer model with the 10 dropped restrictions to minimize the information loss. This implied that there was no loss of accuracy in computing elasticities from the parameter estimates of the profit function while including the 10 restrictions that did not hold.

4.4. Factors influencing antibiotic demand in commercial poultry production in Kiambu County

Tables 4.18presentmaximum likelihood estimates of the antibiotic share equation for the broilerproduction system.Only the antibiotic price had a statistically significant effect on demand for antibiotics among the survey respondents (p=0.003).

Table 4.18.Maximum likelihood estimates of factors influencing antibiotics demand in broiler production in Kiambu County

Variable	Coefficient	Standard error	t-statistic	P>|t|
Antibiotic price	0.0085***	0.003	2.98	0.003
Broiler finisher	-0.003	0.008	-0.38	0.702
Labour	0.001	0.004	0.29	0.773
Capital	0.002	0.003	-0.71	0.480
Land	0.002	0.003	-0.60	0.551
Intercept	0.003	0.042	0.06	0.950

Note: ***denotesignificance at 1percentlevel.
Source:Survey data

Table 4.19 shows the maximum likelihood estimates of the antibiotic share equation for layers. Like in the case of broilers, only the antibiotic price had a statistically significant influence on the demand for antibiotics (p=0.010).

Table 4.19.Maximum likelihood estimates of factors influencing demand for antibiotics in layer production in Kiambu County

Variable	Coefficient	Standard error	t-statistic	P>|t|
Antibiotic price	0.001***	0.002	2.59	0.010
Chick mash	0.002	0.001	0.65	0.517
Growers' mash	-0.001	0.005	-0.47	0.639
Layers' mash	0.009	0.0007	1.62	0.106
Labour	-0.000	0.0004	-0.12	0.902
Capital	-0.001	0.0005	-1.36	0.175
Land	-0.001	0.0007	-1.17	0.242
Intercept	-0.019	0.016	-1.21	0.229

Note: ***denotesignificance at 1percentlevel.
Source:Survey data

All the other variable (feeds and labour) and fixed (capital and land) inputs did not have any effect on antibiotic demand in both broiler and layer production. This could be attributed to the fact that antibiotic is a damage control input and therefore do not compete with other conventional inputs. Hence, changes in prices of other inputs did not have a significance affect the demand for antibiotics.

Table 4.20 presents the maximum likelihood estimates for the profit equation in the broiler production system. Broilers'finisher and labour prices had a statistically significant influence on profit (p=0.002). Own interactions within broiler finisher prices and also labourprice were significant (p= 0.000 and 0.006 respectively). This could be because feeds and labour constitute the largest proportion of costs involved in broiler production (Okello*et al*., 2010)and, therefore, their prices influence the profits significantly.From the survey data, the antibiotic profit share was very small (0.014) compared to the rest of the variable input(labour and feeds) shares.This could have been the reason why its price did not have a significance influence on the profit. However, its own interaction,such that, antibiotic prices squared,was significant (p=0.003),meaning that higher prices of antibiotics are likely to influence profit. Capital (p=0.08) and capita-wage price interactions (p=0.002)also had a significant influence on the profit.Capital (in terms of feeding equipment and infrastructure) in broiler production is expensive which translates to high capital requirements (Okello *et al.*, 2010). This might be the reason why capital and some of its interactions with other inputs had a significant influence on profit.

Table 4.20.Maximum likelihood estimates of factors influencing profit in broilerproduction in Kiambu County

Variable	Coefficient	Standard error	t-statistic	P>|t|
Broiler finisher	2.704**	0.877	3.08	0.002
Antibiotic price	0.002	0.042	0.06	0.950
Labour	1.029**	0.322	3.20	0.002
[Broiler finisher]^2	0.646***	0.149	4.33	0.000
[Antibiotic price]^2	0.009**	0.003	2.98	0.003
[Labour]^2	0.077**	0.028	2.76	0.006
Broiler finisher x Antibiotic price	-0.003	0.008	-0.38	0.702
Broiler finisher x labour	-0.006	0.055	-0.10	0.920
Antibiotic price x Labour	0.001	0.004	0.29	0.773
Broiler finisher x Land	-0.048	0.062	-0.77	0.442
Antibiotic x Land	-0.002	0.003	-0.60	0.551
Labour x Land	0.003	0.023	0.12	0.901
Broiler finisher x Capital	-0.096	0.065	-1.47	0.142
Antibiotic x Capital	-0.002	0.003	-0.71	0.480
Labour x Capital	-0.073**	0.024	-3.06	0.002
Capital	-3.827*	2.17	-1.76	0.079
Land	1.367	1.45	0.94	0.346
[Land]^2	-0.002	0.052	-0.05	0.962
[Capital]^2	0.157	0.097	1.62	0.107
Capital x Land	-0.128	0.102	-1.26	0.208
Intercept	29.729**	13.056	2.28	0.024

Note: ***, **, * denote significance at 1, 5and 10percent levels respectively.
Source:Survey data

In layer production system, layers' mash price (p=0.073) and layer mash prices squared (p=0.026) had a statistically significant effect on profit (Table 4.21). This significance could be explained by the fact feeds constitute about 60 percent of all the cost involved in layer productioncosts (Okello*et al*., 2010). Additionally, from the survey data, layers' mash had the largest average profit share of 0.94.Chick mash and growers' mash feeds were fed to the layers for only a period of 8 and 7 weeks respectively, which means each accounted for a smaller proportion of the variable costs with lower corresponding profit shares of 0.1 and 0.27 respectively on average. This could probably be the reason why their prices did not have a significant influence on profit.

Layers' mash interactions with land (p=0.05), antibiotics price (p=0.10) and growers' mash price (p=0.07) had a significant influence on profit. Antibiotic price did not have a significance influence on the mean antibiotic profit,which could probably be explained by thesmall profit share of antibioticsof 0.0043 in layer production, compared to the profit shares of rest of the variable inputs (labour and feeds).However, the squared antibiotic price term had a significant influence on profit. Capital (p=0.001), capital squared (p=0.06) and capital land interaction (0.023) had a significant influence of profit. The most probable reason why capital influenced profit could bedue to the heavy capital investment required in layer production for the purchase of chicken feeding equipmentand also building the chicken pen (Okello *et al.,* 2010).

Table 4.21. Maximum likelihood estimates of factors influencing profit in layer production in Kiambu County

Variable	Coefficient	Standard error	t-statistic	P>|t|
Chick mash	0.411	0.479	0.86	0.391
Growers' mash	0.960	0615	1.56	0.119
Layers' mash	3.153*	1.751	1.80	0.073
Labour	0.499	0.437	1.14	0.253
Antibiotic	-0.019	0.016	-1.20	0.233
$[\text{Chick mash}]^2$	-0.102	0.067	-1.52	0.129
$[\text{Grower mash}]^2$	-0.023	0.039	-0.60	0.552
$[\text{Layer mash}]^2$	-0.593**	0.265	-2.24	0.026
$[\text{Labour}]^2$	0.001	0.014	0.08	0.936
$[\text{Antibiotic}]^2$	0.001***	0.0005	2.56	0.011
Chick mash x grower mash	0.019	0.356	0.54	0.591
Chick mash x layer mash	-0.190	0.166	-1.15	0.251
Chick mash x labour	-0.009	0.025	-0.35	0.725
Chick mash x antibiotic	0.002	0.002	0.69	0.491
Grower mash x layer mash	-0.478***	0.175	-2.73	0.007
Grower mash x labour	-0.030	0.036	-0.85	0.398
Grower mash x antibiotic	-0.001	0.001	-0.48	0.629
Layer mash x labour	0.021	0.127	0.17	0.868
Layer mash x antibiotic	0.009*	0.005	1.63	0.103
Labour x antibiotic	-0.001	0.0007	-0.12	0.901
Chick mash x capital	0.005	0.19	0.27	0.786
Grower mash x capital	0.009	0.036	0.26	0.796
Layer mash x capital	-0.163	0.12	-1.36	0.174
Labour x capital	-0.034	0.026	-1.32	0.189
Antibiotic x capital	-0.001	0.0005	-1.35	0.178
Chick mash x land	-0.033	0.027	-1.23	0.220
Grower mash x land	-0.054	0.05	-1.09	0.276
Layer mash x land	-0.329**	0.168	-1.95	0.051
Labour x land	-0.018	0.037	-0.50	0.620
Antibiotic x land	-0.001	0.001	-1.07	0.287
Capital	3.401***	1.012	3.36	0.001
Land	-1.022	1.202	-0.85	0.396
Capital x land	-0.077**	0.033	-2.29	0.023
$[\text{Land }]^2$	-0.008	0.0415	-0.18	0.857
$[\text{Capital}]^2$	0.163*	0.087	1.88	0.061
Intercept	-18.237**	9.008	-2.01	0.045

Note: ***, **, * denote significance at 1, 5and 10percent levels respectively.
Source:Survey data

4.5 Elasticity of demand for antibiotics in commercial poultry production in Kiambu County

Table 4.22 shows the elasticity of antibiotic demand in poultry production. In broiler production system, the own price elasticity of demand for antibiotics was negative as expected(see Table 3.1)butstatistically significant (p=0.003). From Table 4.20, a onepercent increase in the price of antibiotics would result in a 1.68percent decrease in the demand, holding all other factors constant. This suggests that the antibiotic demand was sensitive to changes in own price as expected from theory.

The cross-price elasticity of antibiotic demand with respect to wage rate and broiler finisher price was inelastic, having elasticities of less than unity at -0.225 and -0.428 respectively (Table 4.22).However, the effect of wage rate and broiler finisher prices on antibiotic demand was not significant(p=0.702 and p=0.773 respectively).This could probably be due to the fact that antibioticsare damage abatement inputs and therefore their demand is not influenced by the prices of the other conventional variable inputs. The antibiotic demand was most sensitive to producer price of chicken meat. That is, aonepercent increase in price of chicken meat would result in 2.99percent increase in the demand for antibiotics (Table 4.20), *ceteris paribus*.

Table 4.22.Elasticities of antibiotic demand in broiler and layer productionin Kiambu County

Item	Elasticity of antibiotic demand with respect to the item (layer production)	Elasticity of antibiotics demand with respect to the item (broiler production)
Price of antibiotic	-1.2369***	-1.6754***
	(0.10)	(0.003)
Price of chick mash	-0.5698	-
	(0.517)	
Price of growers' mash	-0.0423	-
	(0.639)	
Layer mash price	-3.0325	-
	(0.106)	
Broilers' finisher price	-	-0.4284
		(0.702)
Wage rate	-0.0373	-0.2250
	(0.902)	(0.773)
Price of egg	4.8442	
Price of meat		2.9906

Note: Numbers in brackets are p- values; *** denote significance at 1 percent level.
Source:Survey data

In layer production, the own price elasticity demand for antibiotics was negative but statistically significant (p=0.01) (Table 4.22).This was as expected in the hypothesis(see Table 3.1).Hence, a one percent increase in the price of antibiotics would result in a 1.24 percent decrease in antibiotic demand.

On the other hand, the cross-price elasticity of demand for antibiotics was -0.6, 0.04 and -0.03, with respect to chick, grower and layer mash pricesrespectively.Additionally, it was-0.0423 and -0.0373 with respect to the prices of grower mash and labour, respectively. However, all the cross-price elasticities of demand were not statistically significant (p>0.05). The signs of the cross-price elasticities were as expected (see Table 3.1). Their lack of significance could have been because, like in the case of broilers,antibiotics are a damage abatement input and therefore their demand is not influenced by the prices of t other conventional variable inputs.

With respect of outputelasticity of antibiotic demand,the quantity of antibiotic demanded was most sensitive to producer price of eggs with an elasticity of 4.84 (Table 4.20). Accordingly, a one percent increase in the price of eggs would result in 4.84 percent increase in the demand for antibiotics, *ceteris paribus*.

4.5.1 Discussion

Price elasticities are important in demand studies because they give the actual responsiveness of demand to own and cross prices. The signs of own- and cross- price elasticities from both the broiler and the layer models tallied with thehypotheses(seeTable 3.1). The own-price elasticity of antibiotic demand in both production systemswas negative and significant. Therefore, the hypothesis of the study that the own-price elasticity of antibiotic demand in both production systemsis positive was rejected implyingthat an increase in antibiotics price would lead to a decrease in antibiotic demand. This finding is consistent with production economics theory which states that an increase in the price of an input leads to decreased demand for that input (Varian, 1992).

This study found own-price elasticity of antibiotic demand in broilers and layers to be -1.7 and -1.2,respectively,implying that a one percent increase in antibiotic prices would lead to 1.7 and 1.2 percent decrease in antibiotic demand in broilers and layers production respectively. Rendleman(1993)found an own-price elasticity of aggregate pesticide demandof -1.7in crops in USA, which is comparable to the results of this study.Lin *et al*. (1995)indicate that the demand for individual active ingredients of damage abatement agents is elastic because of availability of alternatives in the long run. This arises because damage-inducing agents tend to tolerate higher doses of control agents thereby prompting farmers to seek alternatives(Lichtenberg and Zilberman, 1986; Fox and Weersink, 1995). In the livestock industry, these alternatives come from continuous research and development (R&D)efforts of veterinary drug companies.The negative and elastic nature of antibiotic demand found in this study suggeststhat manipulating antibiotic prices canbe a strategy forinducingrational use of antibiotics in poultry production.

With regard to output price elasticity of antibiotic demand,the results indicate that a one percent increase in the price of broiler meat would increase antibiotic demand by2.99 percent. Likewise, a one percent increase in eggprice would increase antibiotic price by 4.84 percent.This observation was expected from theoryas an increase in product (either broiler meat or egg) price generally induces farmers to increase production to take advantage of the price rise and, therefore, an increase in their derived demand for inputs such as antibiotics.In France, Bayramoglu and Chakir (2010)found that the priceof rapeseedhad a positive effect on pesticide use although in their case the demand was inelastic. The highand positive output price elasticities of antibiotic demand found in this study suggest that price support to poultry farmers may not be an appropriate strategy to induce rational use antibiotics, at least in Kiambu County.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

This study assessedthe factors affecting the demand for antibiotics in poultry productionin Kiambu County, Kenya. The aim was to evaluate how responsive antibiotic demand is to factor and product prices in order to identify the price incentives potentially available to antibiotics users in poultry production in Kiambu County. Such incentives could potentially be used by policy makers to design strategies aimed at inducing rational use of antibiotics in livestock production.

Two hundred and thirty eight respondents in Kikuyu and Gatundu North districts were sampled using multistage random sampling. The stages included locations, sub-locations, villages, and finally households. The sampled farmers were surveyed using a pre-tested semi-structured questionnaire.The questionnaire collected data on farmers' information, farm characteristics, poultry production costs and revenues and information on antibiotic use. Descriptive statistics were undertaken to describe the social economics characteristics of poultry farmers and the patterns of antibiotics use.A normalized restricted translog profit function and share equations were simultaneously estimated using a Seemingly Unrelated Regression(SUR). Appropriate tests were undertaken to validate the estimated models. The parameters of the translog profit function were used to compute own-price, cross-price and output price elasticity of antibiotic demand among poultry farmers in Kiambu County.

The study found out that poultry farming in Kiambu County was mainly done by middle-aged farmers with overall mean age in the two districts of49 and 50 for broiler and layer farmers respectively. The average number of years of formal education in the layer and broiler production systems in the two districts was 10 and 11 respectively. The overall average years of experience in the two districts were 9 and 11 for broiler and layers farmers respectively. Layer production was more widespread than broiler farming in Kiambu County.

Tetracycline was the most commonly used class of antibiotics with 64 and 52 percent of broiler and layer farmers using them respectively. Over 80 percent of the poultry producers did not useany professional services while administering antibiotics. In addition, only 34 percent of broiler farmers and 26 percent of layer farmers who administered the antibiotics had attended any kind of training on antibiotic use. Most of the farmers who had not undergone any kind of training relied on their past experience for buying and administering antibiotics to their chicken.

Veterinary services were accessible in Kiambu County with a veterinary surgeon and/or an animal health assistant being, on average,less than 4 km from the farmer's homestead.More than 90 percent of the respondents bought antibiotics from agro-vet shops, which were, on average,less than 4 kmfrom the farmer's homestead. Most of the broiler and layer farmers (80 percent for both systems), did not keep any record on veterinary drugs in the two study districts.In general these descriptive statistics indicate that that: (i) antibiotics were widely used in poultry production in Kiambu County, (ii) they were accessible to farmers, mainly from agro-vet shops and (iii) Farmers administer antibiotics without the assistance of professional veterinary personnel. The implication is that these practises increase the likelihood of drug misuse and therefore the probability of increasing antibiotic resistance in poultry.

The estimation of the antibiotic share equation showed that only the own-price had a significant influenceon antibiotic demand in both broiler and layer production systems ($p<0.05$). On the other hand, estimating the translog profit equation showed that in broiler production, broiler finisher prices and broiler finisher price squared had a statistically significant influence on profit ($p=0.002$ and $p=0.000$ respectively). Similarly, labour price ($p=0.002$) and labour price squared ($p=0.006$) were statistically significant in the profit function. Capital ($p=0.08$) and capital-labour price interactions ($p=0.002$) also had a significant influence on the profit (see Table 4.18).

With regard to layers production, layers' mash price ($p=0.073$) and layer mash prices squared ($p=0.026$) had a statistically significant effect on profit in layer production system. Layer mash interactions with land ($p=0.05$), antibiotics price ($p=0.10$) and growers mash price ($p=0.07$) had a significant influence on profit. Capital ($p=0.001$), capital squared ($p=0.06$) and capital land interaction (0.023) also had a significant influence of profit (see Table 4.19).

In the broiler and layer production systems,the own-price elasticity of antibiotic demand was -1.7 and -1.2 respectively, implying high sensitivity of antibiotic demand to antibiotic prices. This meansthat antibiotic price could potentially be an attractive strategy to induce rational use of antibiotics in poultry production in Kiambu County. The cross-price elasticity of antibiotic demand was less than unity in absolute termsforfeed and labourprices inboth production systems. However,the cross-price elasticity of antibiotic demand with respect to layers' mash price was 3.03 in layer production. Additionally, the effect of the cross-price elasticitieson antibiotic demand was not statistically significant ($p>0.05$). This implies that a pricesupport policyforpoultry feeds and labour prices would not be an appropriate strategy for controlling antibiotic use.

The output price elasticities of antibiotic demand were 3.0 and 4.8 for chicken meat and eggrespectively. This means that chicken meat and egg prices were importantin influencing the demand for antibiotics among the respondents. Accordingly, changes in output (chicken meat and eggs) price would have a great influence on the antibiotic demand and could potentially be used by policy makers to induce rational use of antibiotics poultry production in Kiambu County.

5.2 Conclusions

This study was motivated by lack of information on the price incentives available to poultry producers to use antibiotics. The study characterized the patterns of use for antibiotics in poultry production in Kiambu County. A normalized restricted translog profit function and share equations were then simultaneously estimated using SUR. The parameters of the translog profit function were used to compute own-price, cross-price and output price elasticity of antibiotic demand.

The results show there is widespread use of antibiotics in poultry production in Kiambu County, which previous studies associate with increasing levels of antimicrobial resistance.Most of the farmers easily acquired antibiotics from agro-vet shops which they self-administered antibiotics unsupervised by veterinary professionals, a practice that has potential for drug misuse and therefore increases the risk of development of antibiotic resistance.

Based on the input price elasticity of antibiotic demand generated, and as expected from theory, antibiotic price emerged as a key determinant of antibiotic demand in the two production systems. This observation suggests that antibiotic consumption policies should focus on controlling antibiotics prices to induce rational use. The insignificant and negative cross-price elasticity of antibiotic demand found in this study means that a large change in wage rates and feed prices would only cause a minimal change in antibiotic demand.Given that it is desirable to reduce the risk of development of antibiotic resistance in poultry through reduced antibiotic use, increasing feed and labor prices to induce rational antibiotics use would end up jeopardizing both producer and consumer welfare and yet yield minimal changes in antibiotic use.However, it would increase government revenue especially if implemented through a tax policy.

The output price had a huge influence on antibiotic demand among the study farmers. Hence, an output price policycould potentially beuseful in inducing rational antibiotic use. However, manipulating output price may not be feasible; for instance, reducing output price to achieve reduced use of antibiotics may hurt producer welfare, given the high cost of the rest of the variable inputs especially feeds and labour, which constitute the largest proportion of input cost in poultry production. Also, manipulating the output price would depend on other factors which are not addressed in the study such as own-price elasticity of output supply. Therefore, given the scope of the study, focus on antibiotic prices to drive rational use in commercial poultry production would be a more appropriate and potentially feasible strategy.

5.3Recommendations

This study found that antibiotic price is one of the incentives that influence antibiotic use.Therefore, rational use of antibiotics could be strengthened by policy makers manipulating antibiotic prices. Increasing the prices of antibiotics to reduce the demand through an antibiotic “pigouvian” tax policy can achieve a significant reduction in antibiotic use.Poultry farmers have alternative recourse to antibiotic use, namely, improving hygiene and sanitation of chicken houses and birds, vaccination. However,such a price increase should be protected by a legal mechanism that guards against emergence of a parallel black market particularly through cross-border trade.

The high and positive output price elasticities of antibiotic demand imply that an output price rise serves as an incentive to farmers to use more antibiotics to increase poultry production. Therefore,farm output price support, which is often justified from a political viewpoint, isunlikely to reduce antibiotic use in poultry production.Hence, supporting the activities of the Pharmacy and Poisons Boardand the Department of Veterinary Services in monitoring and regulating the use of antibiotics as egg boosters in layers and growth promoters in broilers ismore likely to reduce the risk of development of antibiotic resistance in poultry in Kenya.

5.4Areas for further research

1. There isneed to extend the studyto cover the rest of the livestock sub-sector and most importantly, large animals, which are the biggest consumers of antibiotics in the country,(see Mitema *et al*., 2001).
2. The current study faced a lot of challengesobtaining literature to support the results because so far little research has been conducted on the subject in Kenya. Therefore, an aggregate national demand analysis of livestock antibiotics would be an important literature which will act as a benchmark for any future study undertaken on antibiotics.
3. A study to determine the welfare effects of a pigouvian tax on antibiotic prices in Kenya would help in identifying the effectiveness of using the tax as a strategy to reduce the impacts of antibiotic misuse as well as to identify the potential gainers and losers of such a policy.

4. Finally, a study on other non-price incentives(such as trainings) that influence antibiotic consumption would be also useful to policy makers in formulating qualitative policies to strengthen the recommended policies.

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APPENDICES

Appendix I: Test for symmetry condition for the broiler's model

Symmetry Conditions	F-Value	Prob>F
[finishare]lnantib - [antishare]lnfinisher = 0	0.72	0.3985
[finishare]lnlabor - [laborshare]lnfinisher = 0	0.19	0.6642
[laborshare]lnantib-[antishare]lnlabor = 0	1.27	0.2615
[lnprofit]lnfinishlnfinish - [finishare]lnfinisher = 0	2.90	0.0901
[lnprofit]lnlaborlnlabor - [laborshare]lnlabor = 0	1.33	0.2501
[lnprofit]lnantiblnantib - [antishare]lnantib = 0	0.48	0.4885
[lnprofit]lnfinishlnantib - [finishare]lnantib = 0	0.49	0.4842
[lnprofit]lnfinishlnlabor - [finishare]lnlabor = 0	0.04	0.8362
[lnprofit]lnantiblnlabour - [antishare]lnlabor = 0	0.29	0.5933
[lnprofit]lnfinishlnland - [finishare]lnland = 0	1.41	0.2365
[lnprofit]lnfinishlncapita - [finishare]lncapita = 0	0.02	0.8766
[lnprofit]lnantiblncapita - [antishare]lncapita = 0	0.00	0.9736
[lnprofit]lnantiblnland - [antishare]lnland = 0	0.83	0.3638
[lnprofit]lnlaborlnland - [laborshare]lnland = 0	0.66	0.4175
[lnprofit]lnlaborlncapita - [laborshare]lncapita = 0	0.33	0.5689
[lnprofit]lnfinisher - [finishare]_cons = 0	0.24	0.6282
[lnprofit]lnlabor - [laborshare]_cons = 0	0.11	0.7448
[lnprofit]lnantib - [antishare]_cons = 0	0.91	0.3398

Appendix II: Symmetry conditions for the layer model

Symmetry Conditions	F-value	Prob>F
[chickshare]lngrower-[growershare]lnchick=0	0.05	0.8163
[chickshare]lnlayer - [layershare]lnchick = 0	5.31	0.0217
[chickshare]lnlabor - [laborshare]lnchick = 0	0.40	0.5266
[chickshare]lnantib - [antibshre]lnchick = 0	0.27	0.6046
[growershare]lnlayer - [layershare]lngrower = 0	0.41	0.5217
[growershare]lnlabor - [laborshare]lngrower = 0	0.00	0.9879
[growershare]lnantib - [antibshre]lngrower = 0	0.16	0.6921
[layershare]lnlabor - [laborshare]lnlayer = 0	0.02	0.8962
[layershare]lnantib - [antibshre]lnlayer = 0	0.13	0.7150
[laborshare]lnantib - [antibshre]lnlabor = 0	0.30	0.587
[lnprofit]lnchicklnchick - [chickshare]lnchick = 0	11.24	0.0009
[lnprofit]lngrowerlngrower - [growershare]lngrower = 0	0.02	0.8935
[lnprofit]lnlayerlnlayer - [layershare]lnlayer = 0	3.11	0.0784
[lnprofit]lnlaborlnlabor - [laborshare]lnlabor = 0	0.54	0.4641
[lnprofit]lnantiblnantib - [antibshre]lnantib = 0	0.88	0.3493
[lnprofit]lnchicklngrower - [chickshare]lngrower = 0	0.21	0.6481
[lnprofit]lnchicklnlayer - [chickshare]lnlayer = 0	1.46	0.2280
[lnprofit]lnchicklnlabor - [chickshare]lnlabor = 0	0.47	0.4928
[lnprofit]lnchicklnantib - [chickshare]lnantib = 0	2.45	0.1185
[lnprofit]lngrowerlnlayer - [growershare]lnlayer = 0	0.03	0.8737
[lnprofit]lngrowerlnlabor - [growershare]lnlabor = 0	0.02	0.8883
[lnprofit]lngrowerlnantib - [growershare]lnantib = 0	0.28	0.5974
[lnprofit]lnlayerlnlabor - [layershare]lnlabor = 0	31.57	0.0000
[lnprofit]lnlayerlnantib - [layershare]lnantib = 0	14.80	0.0001
[lnprofit]lnlaborlnantib - [laborshare]lnantib = 0	2.31	0.1290
[lnprofit]lnchicklncapita - [chickshare]lncapita = 0	0.96	0.3270
[lnprofit]lnchicklnland - [chickshare]lnland = 0	1.52	0.2179
[lnprofit]lngrowerlnland - [growershare]lnland = 0	1.13	0.2887
[lnprofit]lngrowerlncapita - [growershare]lncapita = 0	0.42	0.5194
[lnprofit]lnlayerlncapita - [layershare]lncapita = 0	18.78	0.0000
[lnprofit]lnlayerlnland - [layershare]lnland = 0	0.57	0.4520
[lnprofit]lnlaborlnland - [laborshare]lnland = 0	27.97	0.0000
[lnprofit]lnlaborlncapita - [laborshare]lncapita = 0	1.30	0.2550
[lnprofit]lnantiblncapita - [antibshre]lncapita = 0	7.42	0.0067
[lnprofit]lnantiblnland - [antibshre]lnland = 0	0.02	0.8831
[lnprofit]lnchick - [chickshare]_cons = 0	0.71	0.0093
[lnprofit]lngrower - [growershare]_cons = 0	0.96	0.3288
[lnprofit]lnlayer - [layershare]_cons = 0	1.25	0.2639
[lnprofit]lnlabor - [laborshare]_cons = 0	11.96	0.0006
[lnprofit]lnantib - [antibshre]_cons = 0	16.60	0.0001

Appendix III: Estimates for Layers' translog profit function with dropped restrictions

Variable	Coefficient	Standard errors	t-statistic	P>|t|
chick mash	-3.400**	1.434	-2.37	0.018
grower mash	0.914	0.627	1.46	0.146
layer mash	-9.957***	3.364	-2.96	0.003
labour	-11.388***	2.665	-4.27	0.000
antibiotic	5.984***	1.731	3.46	0.001
[chick mash]^2	1.113***	0.438	2.54	0.011
[grower mash]^2	-0.066**	0.036	-1.83	0.068
[layer mash]^2	4.348***	1.126	3.86	0.000
[labour]^2	0.043*	0.024	1.79	0.075
[antibiotic]^2	0.001**	0.004	2.05	0.041
chick mash x grower mash	-0.007	0.035	-0.19	0.851
chick mash x layer mash	-0.227	0.206	-1.10	0.272
chick mash x labour	0.003	0.274	0.09	0.926
chick mash x antibiotic	0.003	0.003	1.18	0.241
grower mash x layer mash	-0.416**	0.190	-2.19	0.029
grower mash x labour	-0.027	0.035	-0.75	0.452
grower mash x antibiotic	-0.001	0.001	-0.52	0.605
layer mash x labour	7.784***	1.263	6.17	0.000
layer mash x antibiotic	-2.464***	0.739	-3.33	0.001
labour x antibiotic	0.001	0.0008	0.69	0.491
chick mash x capital	0.003	0.019	0.14	0.885
grower mash x capital	0.010	0.358	0.27	0.786
layer mash x capital	-1.498***	0.387	-3.87	0.000
labour x capital	-0.044*	0.026	-1.72	0.086
antibiotic x capital	-0.064	0.05	-1.29	0.197
chick mash x land	-0.032	0.027	-1.19	0.234
grower mash x land	-0.053	0.05	-1.07	0.287
layer mash x land	-0.268	0.162	-1.65	0.099
labour x land	0.840***	0.2	4.21	0.000
antibiotic x land	-0.001	0.0008	-1.05	0.296
capital	5.000***	1.139	4.39	0.000
land	-2.423**	1.089	-2.23	0.027
capital x land	-0.035	0.027	-1.30	0.195
[land]^2	-0.001	0.033	-0.03	0.976
[capital]^2	-0.061	0.072	0.84	0.404
Intercept	-14.448	9.154	-1.58	0.115

Note: ***, **, * denote significance at 1 percent, 5 percent and 10 percent levels respectively

Appendix IV. Smallholder farmers' questionnaire

ANALYSIS OF DEMAND FOR ANTIBIOTICS IN POULTRY PRODUCTION IN KIAMBU COUNTY, KENYA

Enumerator's name; ___________________________________**DATE**: ..../............/2012

SECTION A: IDENTITY

A1.Household Identification number HHID; ________________

A2.Name of the respondent;

____

A3.Gender of the respondent; ________________________________ male =1 female=2

A4.Relationship of respondent to household head; _______________________ ***codes are given below***

A5. Name of the household head____

A6. Gender _________________________________ male=1 female=2

A7.Age ____

A8.Years of formal education____

A9.Type of the farm____ household=1, commercial =2

A10.Farmer's telephone No. ____

		Name	code
A9	District		
A10	division		
A11	location		
A12	sub location		
A13	village		

A4codes

1=	selfhh head	7=	Grandparent
2=	Spouse	8=	aunt/uncle
3=	son/ daughter	9=	nephew/niece
4=	mother/father	10=	domestic servants
5=	brother/sister	11=	others specify
6=	grandchildren		_______________________

A11.How many people constantly live, eat and cook at this household? __________________________

A12.What is the primary occupation of the household head?

____

SECTION B: FARM CHARACTERISTICS

B1.How many acres of land do you own?

____

B2.How many acres of land have you rented?

____

B3. Of the land you have, how many acres do you use for agriculture?

____

B4.What is the approximate distance of the farm to the nearest:

	km		**km**
Vet. Doctor		Market Centre	
Animal health assistance		Major town	
Agro vet shop		All weather road	
Shopping Centre			

SECTION C: POULTRY PRODUCTION PRACTICES AND ANTIBIOTICS USE

C1.Do you keep Layers or Broilers? _____________________ {1= Layers, 2= Broilers, 3=Both}

C2.In which year did you establish the poultry enterprise?

____

C3.What is the size of land used for the poultry production?

____

C4. Which antibiotics do you use on poultry, for what purpose are they used?

Antibiotic	**Growth stage**	**Purpose**	**Dosage**	**frequency**

A list of common antibiotics in poultry production

1=Agracox	2=OTC dawa	3=alamycin	4=quinol-erofloxacin
5=tetracyclin	6=miramed	7=colesultrix	8=Sulfadimidin
9=Hipralona	10=Doxin	11=aliseryl	12=limoxin
13=skazon	14=Medicox	15=ESB30	16=Sulfonamides
17=0thers specify____			

Codes for frequency;

1=weekly	3=monthly	5=semi annually
2=fortnight	4=quarterly	6= others specify_______________

C5. **Layers information for the last 3 months**

	Unit.	**Unit price**	**Month 1**		**Month 2**		**Month 3**	
Initial costs			Qty	Total.	Qty	Total.	Qty	Total.
Day old chicks	No							
House construction	No							
Lamps	No.							
Feed/watching troughs	No.							
Others specify								
Output								
Eggs	Trays							
Culled birds	No.							
Manure	Tons							
Variable costs								
Chick mash	70kg bag							
Growers mash	70kg bag							
Other feeds specify								
Deworming	No.							
Vaccinations	No.							
Paraffin	lts							
Vet. Services	No.							
Antibiotics	Ltr/Kg							
Trays paper	No.							
Labour	man.days							

C6. **Broilers information for the last 3 months**

	Unit.	**Unit price**	**Month 1**		**Month 2**		**Month 3**	
Initial costs			Qty	Total.	Qty	Total.	Qty	Total.
Day old chicks	No							
House construction	No							
Lamps	No.							
Feed/watching troughs	No.							
Others specify								
Output								
chicken meat	kgs							
Manure	Tons							
Variable costs								
broilers mash	70kg bag							
finishers mash	70kg bag							
Other feeds specify								
Deworming	No.							
Vaccinations	No.							
Paraffin	lts							
Vet. Services	No.							
Antibiotics	Ltr/kg							
Labour	man.days							

SECTION D: KAP Knowledge, attitudes and practices ON ANTIBIOTICS USE

D1.When do you decide to use an antibiotic? [____________________]

1=When the vet prescribes or recommends it

2=When I see symptoms that I know they can be treated with antibiotics

3=When friends or family recommend that I do

4=others specify ____

D2.Who buy/ administers the antibiotics used in your poultry? [________________]

1=household head ____________________

2=spouse

3= son/ daughter

4= farmworker

5=A vet doctor

6=other specify ____

D3.Does the person who buys/ administers these antibiotics consult? [______] 1=YES 2=NO.

D4.IF YES, who does he/she consult? [____________________]
1=A vet doctor
2= agro-vet operator
3=other specify ______________________

D5.Do the one who buys/administers the antibiotics has any training on the use of antibiotics? [_________] 1=YES 2=NO.

D6.IF YES, what kind of training?
____
____
____
____

D7.If NO, how does s/he know how to use an antibiotic?
____
____
____
____

D8.After administering an antibiotic treatment on the poultry, how long do you wait before selling the product?

Antibiotic	**Period before sale**

D9.Where do you market your products?
____

D10.Does the market influences the use of antibiotics in your poultry? [_______] 1=YES 2=NO.
D11.IF YES, how? ____

Appendix V: Estimates of translog profit function and share equations for Broiler system

```
Iteration 1:   tolerance =   .3634233
Iteration 2:   tolerance =  .06414415
Iteration 3:   tolerance =  .01610521
Iteration 4:   tolerance =  .00149413
Iteration 5:   tolerance =  .00013057
Iteration 6:   tolerance =  .00001141
Iteration 7:   tolerance =  9.999e-07

Seemingly unrelated regression, iterated
```

Equation	Obs	Parms	RMSE	"R-sq"	F-Stat	P
lnprofit	70	20	.8243167	0.3218	15.42	0.0000
finishare	70	5	.3963515	0.2342	8.00	0.0000
laborshare	70	5	.1433161	0.1183	3.03	0.0113
antishare	70	5	.0170743	0.1385	2.06	0.0718

```
 ( 1)  [finishare]lnantib - [antishare]lnfinisher = 0
 ( 2)  [finishare]lnlabor - [laborshare]lnfinisher = 0
 ( 3)  - [laborshare]lnantib + [antishare]lnlabor = 0
 ( 4)  [lnprofit]lnfinishlnfinish - [finishare]lnfinisher = 0
 ( 5)  [lnprofit]lnlaborlnlabor - [laborshare]lnlabor = 0
 ( 6)  [lnprofit]lnantiblnantib - [antishare]lnantib = 0
 ( 7)  [lnprofit]lnfinishlnantib - [finishare]lnantib = 0
 ( 8)  [lnprofit]lnfinishlnlabor - [finishare]lnlabor = 0
 ( 9)  [lnprofit]lnantiblnlabour - [antishare]lnlabor = 0
 (10)  [lnprofit]lnfinishlnland - [finishare]lnland = 0
 (11)  [lnprofit]lnfinishlncapita - [finishare]lncapita = 0
 (12)  [lnprofit]lnantiblncapita - [antishare]lncapita = 0
 (13)  [lnprofit]lnantiblnland - [antishare]lnland = 0
 (14)  [lnprofit]lnlaborlnland - [laborshare]lnland = 0
 (15)  [lnprofit]lnlaborlncapita - [laborshare]lncapita = 0
 (16)  [lnprofit]lnfinisher - [finishare]_cons = 0
 (17)  [lnprofit]lnlabor - [laborshare]_cons = 0
 (18)  [lnprofit]lnantib - [antishare]_cons = 0
```

	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnprofit						
lnfinisher	2.704982	.8771061	3.08	0.002	.9772091	4.432755
lnantib	.0026343	.0416394	0.06	0.950	-.0793894	.084658
lnlabor	1.029407	.322127	3.20	0.002	.3948628	1.66395
lnfinishln~h	.6455008	.1490303	4.33	0.000	.3519325	.9390691
lnantiblna~b	.0085368	.0028619	2.98	0.003	.0028992	.0141744
lnlaborlnl~r	.0769551	.0278662	2.76	0.006	.0220626	.1318476
lnfinishln~b	-.0031302	.0081701	-0.38	0.702	-.0192242	.0129638
lnfinishln~r	-.005517	.0551634	-0.10	0.920	-.114181	.103147
lnantiblnl~r	.0011705	.0040596	0.29	0.773	-.0068263	.0091673
lnfinishln~d	-.0478591	.0621784	-0.77	0.442	-.1703416	.0746235
lnantiblnl~d	-.0016491	.0027638	-0.60	0.551	-.0070934	.0037951
lnlaborlnl~d	.0028493	.0228089	0.12	0.901	-.042081	.0477795
lnfinishln~a	-.0955666	.0648547	-1.47	0.142	-.223321	.0321878
lnantiblnc~a	-.0020514	.0028991	-0.71	0.480	-.0077622	.0036594
lnlaborlnc~a	-.0730675	.0238419	-3.06	0.002	-.1200326	-.0261024
lncapita	-3.827491	2.172802	-1.76	0.079	-8.107599	.4526165
lnland	1.3665	1.446107	0.94	0.346	-1.482122	4.215122
lnlandlnland	-.002487	.051816	-0.05	0.962	-.1045571	.099583
lncapitaln~a	.1567522	.0968914	1.62	0.107	-.0341099	.3476144
lncapitaln~d	-.1282375	.1016331	-1.26	0.208	-.3284401	.0719652
_cons	29.72877	13.05557	2.28	0.024	4.011169	55.44636
finishare						
lnfinisher	.6455008	.1490303	4.33	0.000	.3519325	.9390691
lnantib	-.0031302	.0081701	-0.38	0.702	-.0192242	.0129638
lnlabor	-.005517	.0551634	-0.10	0.920	-.114181	.103147
lncapita	-.0955666	.0648547	-1.47	0.142	-.223321	.0321878
lnland	-.0478591	.0621784	-0.77	0.442	-.1703416	.0746235
_cons	2.704982	.8771061	3.08	0.002	.9772091	4.432755
laborshare						
lnlabor	.0769551	.0278662	2.76	0.006	.0220626	.1318476
lnantib	.0011705	.0040596	0.29	0.773	-.0068263	.0091673
lnfinisher	-.005517	.0551634	-0.10	0.920	-.114181	.103147
lncapita	-.0730675	.0238419	-3.06	0.002	-.1200326	-.0261024
lnland	.0028493	.0228089	0.12	0.901	-.042081	.0477795
_cons	1.029407	.322127	3.20	0.002	.3948628	1.66395
antishare						
lnantib	.0085368	.0028619	2.98	0.003	.0028992	.0141744
lnfinisher	-.0031302	.0081701	-0.38	0.702	-.0192242	.0129638
lnlabor	.0011705	.0040596	0.29	0.773	-.0068263	.0091673
lncapita	-.0020514	.0028991	-0.71	0.480	-.0077622	.0036594
lnland	-.0016491	.0027638	-0.60	0.551	-.0070934	.0037951
_cons	.0026343	.0416394	0.06	0.950	-.0793894	.084658

Appendix VI: Estimates for translog profit function and share equations for layers' system

```
Iteration 1:   tolerance =   1.300987
Iteration 2:   tolerance =   .1912019
Iteration 3:   tolerance =  .02653628
Iteration 4:   tolerance =  .00223071
Iteration 5:   tolerance =  .00027222
Iteration 6:   tolerance =  .00003735
Iteration 7:   tolerance =  5.200e-06
Iteration 8:   tolerance =  7.246e-07
```

Seemingly unrelated regression, iterated

Equation	Obs	Parms	RMSE	"R-sq"	F-Stat	P
lnprofit	78	35	1.015026	0.1264	5.21	0.0000
chickshare	78	7	.1776804	0.0329	0.60	0.7531
growershare	78	7	.3362837	0.0446	1.53	0.1549
layershare	78	7	1.138135	0.0377	3.06	0.0038
laborshare	78	7	.2474526	0.0278	0.37	0.9216
antibshre	78	7	.0050074	0.1082	1.66	0.1172

```
 ( 1)  [chickshare]lngrower - [growershare]lnchick = 0
 ( 2)  [chickshare]lnlayer - [layershare]lnchick = 0
 ( 3)  [chickshare]lnlabor - [laborshare]lnchick = 0
 ( 4)  [chickshare]lnantib - [antibshre]lnchick = 0
 ( 5)  [growershare]lnlayer - [layershare]lngrower = 0
 ( 6)  [growershare]lnlabor - [laborshare]lngrower = 0
 ( 7)  [growershare]lnantib - [antibshre]lngrower = 0
 ( 8)  [layershare]lnlabor - [laborshare]lnlayer = 0
 ( 9)  [layershare]lnantib - [antibshre]lnlayer = 0
 (10)  [laborshare]lnantib - [antibshre]lnlabor = 0
 (11)  [lnprofit]lnchicklnchick - [chickshare]lnchick = 0
 (12)  [lnprofit]lngrowerlngrower - [growershare]lngrower = 0
 (13)  [lnprofit]lnlayerlnlayer - [layershare]lnlayer = 0
 (14)  [lnprofit]lnlaborlnlabor - [laborshare]lnlabor = 0
 (15)  [lnprofit]lnantiblnantib - [antibshre]lnantib = 0
 (16)  [lnprofit]lnchicklngrower - [chickshare]lngrower = 0
 (17)  [lnprofit]lnchicklnlayer - [chickshare]lnlayer = 0
 (18)  [lnprofit]lnchicklnlabor - [chickshare]lnlabor = 0
 (19)  [lnprofit]lnchicklnantib - [chickshare]lnantib = 0
 (20)  [lnprofit]lngrowerlnlayer - [growershare]lnlayer = 0
 (21)  [lnprofit]lngrowerlnlabor - [growershare]lnlabor = 0
 (22)  [lnprofit]lngrowerlnantib - [growershare]lnantib = 0
 (23)  [lnprofit]lnlayerlnlabor - [layershare]lnlabor = 0
 (24)  [lnprofit]lnlayerlnantib - [layershare]lnantib = 0
 (25)  [lnprofit]lnlaborlnantib - [laborshare]lnantib = 0
 (26)  [lnprofit]lnchicklncapita - [chickshare]lncapita = 0
 (27)  [lnprofit]lnchicklnland - [chickshare]lnland = 0
 (28)  [lnprofit]lngrowerlnland - [growershare]lnland = 0
 (29)  [lnprofit]lngrowerlncapita - [growershare]lncapita = 0
 (30)  [lnprofit]lnlayerlncapita - [layershare]lncapita = 0
 (31)  [lnprofit]lnlayerlnland - [layershare]lnland = 0
 (32)  [lnprofit]lnlaborlnland - [laborshare]lnland = 0
 (33)  [lnprofit]lnlaborlncapita - [laborshare]lncapita = 0
 (34)  [lnprofit]lnantiblncapita - [antibshre]lncapita = 0
 (35)  [lnprofit]lnantiblnland - [antibshre]lnland = 0
 (36)  [lnprofit]lnchick - [chickshare]_cons = 0
 (37)  [lnprofit]lngrower - [growershare]_cons = 0
 (38)  [lnprofit]lnlayer - [layershare]_cons = 0
 (39)  [lnprofit]lnlabor - [laborshare]_cons = 0
 (40)  [lnprofit]lnantib - [antibshre]_cons = 0
```

	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnprofit						
lnchick	.4111237	.4786834	0.86	0.391	-.5299841	1.352232
lngrower	.9601541	.6148274	1.56	0.119	-.2486175	2.168926
lnlayer	3.153268	1.751491	1.80	0.073	-.290223	6.596759
lnlabor	.499328	.4366113	1.14	0.253	-.3590647	1.357721
lnantib	-.018728	.0156672	-1.20	0.233	-.0495302	.0120742
lnchicklnc~k	-.1016551	.0667601	-1.52	0.129	-.2329078	.0295976
lngrower~wer	-.0231344	.0388367	-0.60	0.552	-.0994887	.05322
lnlayerln~er	-.5925797	.2645562	-2.24	0.026	-1.112706	-.0724532
lnlaborlnl~r	.0011297	.0140175	0.08	0.936	-.0264293	.0286886
lnantiblna~b	.0011834	.000463	2.56	0.011	.0002731	.0020937
lnchicklng~r	.0191357	.0355675	0.54	0.591	-.0507912	.0890627
lnchickl~yer	-.190439	.1658083	-1.15	0.251	-.5164237	.1355458
lnchickln~or	-.0088229	.0251059	-0.35	0.725	-.0581819	.0405361
lnchicklna~b	.0017115	.0024826	0.69	0.491	-.0031694	.0065925
lngrower~yer	-.4778879	.1750927	-2.73	0.007	-.8221261	-.1336496
lngrowerl~or	-.0302015	.035702	-0.85	0.398	-.1003928	.0399898
lngrowerln~b	-.0005252	.0010879	-0.48	0.629	-.002664	.0016135
lnlayerln~or	.0210621	.1269031	0.17	0.868	-.2284337	.2705578
lnlayerlna~b	.0088499	.0054131	1.63	0.103	-.0017925	.0194922
lnlaborlna~b	-.0000879	.0007047	-0.12	0.901	-.0014734	.0012975
lnchicklnc~a	.0051657	.0190346	0.27	0.786	-.0322571	.0425884
lngrowerln~a	.0092521	.0357772	0.26	0.796	-.0610871	.0795912
lnlayerlnc~a	-.1634212	.1200772	-1.36	0.174	-.3994971	.0726548
lnlaborlnc~a	-.0343763	.0261086	-1.32	0.189	-.0857068	.0169541
lnantiblnc~a	-.0007253	.0005372	-1.35	0.178	-.0017815	.0003309
lnchicklnl~d	-.0325976	.0265114	-1.23	0.220	-.0847199	.0195247
lngrowerln~d	-.054217	.0496792	-1.09	0.276	-.1518881	.043454
lnlayerlnl~d	-.3289007	.1683124	-1.95	0.051	-.6598086	.0020071
lnlaborlnl~d	-.0181499	.036526	-0.50	0.620	-.0899612	.0536614
lnantiblnl~d	-.0008228	.0007717	-1.07	0.287	-.00234	.0006944
lncapita	3.400563	1.012117	3.36	0.001	1.410706	5.39042
lnland	-1.022076	1.202296	-0.85	0.396	-3.38583	1.341679
lncapitaln~a	-.0765036	.0334555	-2.29	0.023	-.1422783	-.0107288
lnlandlnland	-.0075107	.0415252	-0.18	0.857	-.0891507	.0741293
lncapitaln~d	.1629481	.0867007	1.88	0.061	-.0075084	.3334046
_cons	-18.23691	9.068482	-2.01	0.045	-36.06585	-.4079615
chickshare						
lnchick	-.1016551	.0667601	-1.52	0.129	-.2329078	.0295976
lngrower	.0191357	.0355675	0.54	0.591	-.0507912	.0890627
lnlayer	-.190439	.1658083	-1.15	0.251	-.5164237	.1355458
lnlabor	-.0088229	.0251059	-0.35	0.725	-.0581819	.0405361
lnantib	.0017115	.0024826	0.69	0.491	-.0031694	.0065925
lncapita	.0051657	.0190346	0.27	0.786	-.0322571	.0425884
lnland	-.0325976	.0265114	-1.23	0.220	-.0847199	.0195247
_cons	.4111237	.4786834	0.86	0.391	-.5299841	1.352232
growershare						
lnchick	.0191357	.0355675	0.54	0.591	-.0507912	.0890627
lngrower	-.0231344	.0388367	-0.60	0.552	-.0994887	.05322
lnlayer	-.4778879	.1750927	-2.73	0.007	-.8221261	-.1336496
lnlabor	-.0302015	.035702	-0.85	0.398	-.1003928	.0399898
lnantib	-.0005252	.0010879	-0.48	0.629	-.002664	.0016135
lncapita	.0092521	.0357772	0.26	0.796	-.0610871	.0795912
lnland	-.054217	.0496792	-1.09	0.276	-.1518881	.043454
_cons	.9601541	.6148274	1.56	0.119	-.2486175	2.168926
layershare						
lnchick	-.190439	.1658083	-1.15	0.251	-.5164237	.1355458
lngrower	-.4778879	.1750927	-2.73	0.007	-.8221261	-.1336496
lnlayer	-.5925797	.2645562	-2.24	0.026	-1.112706	-.0724532
lnlabor	.0210621	.1269031	0.17	0.868	-.2284337	.2705578
lnantib	.0088499	.0054131	1.63	0.103	-.0017925	.0194922
lncapita	-.1634212	.1200772	-1.36	0.174	-.3994971	.0726548
lnland	-.3289007	.1683124	-1.95	0.051	-.6598086	.0020071
_cons	3.153268	1.751491	1.80	0.073	-.290223	6.596759
laborshare						
lnchick	-.0088229	.0251059	-0.35	0.725	-.0581819	.0405361
lngrower	-.0302015	.035702	-0.85	0.398	-.1003928	.0399898
lnlayer	.0210621	.1269031	0.17	0.868	-.2284337	.2705578
lnlabor	.0011297	.0140175	0.08	0.936	-.0264293	.0286886
lnantib	-.0000879	.0007047	-0.12	0.901	-.0014734	.0012975
lncapita	-.0343763	.0261086	-1.32	0.189	-.0857068	.0169541
lnland	-.0181499	.036526	-0.50	0.620	-.0899612	.0536614
_cons	.499328	.4366113	1.14	0.253	-.3590647	1.357721
antibshre						
lnchick	.0017115	.0024826	0.69	0.491	-.0031694	.0065925
lngrower	-.0005252	.0010879	-0.48	0.629	-.002664	.0016135
lnlayer	.0088499	.0054131	1.63	0.103	-.0017925	.0194922
lnlabor	-.0000879	.0007047	-0.12	0.901	-.0014734	.0012975
lnantib	.0011834	.000463	2.56	0.011	.0002731	.0020937
lncapita	-.0007253	.0005372	-1.35	0.178	-.0017815	.0003309
lnland	-.0008228	.0007717	-1.07	0.287	-.00234	.0006944
_cons	-.018728	.0156672	-1.20	0.233	-.0495302	.0120742