DISSERTATION

ECONOMIC PERFORMANCE OF SMALLHOLDER EXOTIC DAIRY CATTLE IN THE MARGINAL ZONES OF KENYA

Submitted by

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY MUTUKU MUENDO KAVOI ENTITLED: ECONOMC PERFORMANCE OF SMALLHOLDER EXOTIC DAIRY CATTLE IN THE MARGINAL ZONES OF KENYA BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

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ABSTRACT OF DISSERTATION

ECONOMC PERFORMANCE OF SMALLHOLDER EXOTIC DAIRY CATTLE IN THE MARGINAL ZONES OF KENYA

Kenya's Dairy experts in 1970s argued that the "dry marginal zones" could not meet the requirements of the high performing exotic breeds. They recommended the use of upgraded indigenous breeds which have a lower nutritive requirements and greater adaptability even though their milk supply response capability is relatively low. Yet, smallholder farmers have defied expert advice and have instead shown preference for high exotic grade breeds as a key component of their improved milk production strategies. Does this imply that exotic breeds are more profitable than the indigenous breeds? Experts base their advice on research in the high potential zones, not on marginal zones. The common use of exotic breeds by local farmers in the marginal zones provides an opportunity for an applied research project to compare the performance of these two types of cattle breeds.

Data on dairy farm operations for the period July 2005 to June 2006 is collected and analysed. Three different methodological approaches are applied to determine the performance of dairy farms; (i) stochastic cost frontier to determine economic efficiency; (ii) translog cost function-input demand systems; and, (iii) translog profit function-input demand systems were used to determine various elasticitis and important details on production systems such as input substitutions and economies of scale.

The results indicate that exotic breeds performed better than indigenous breeds: The large breeds have the lowest cost inefficiency. Overall, the mean cost inefficiency of dairy production in the marginal zones is 27.45 %. The resource use inefficiency is significantly explained by institutional and socio-economic factors with varying marginal impacts of the respective variables.

The internal workings of the production and marketing systems shows that dairy farmers maximize profits and that there are no constant returns to scale. Most of the dairy inputs are complements and the dairy establishment faces diseconomies of scale. The supply response analysis indicates that institutional and socio-economic factors have much greater elastic impacts on dairy production than the price factors. In sum, a further liberalization of the dairy sector would be beneficial to stimulate supply response. However, institutional and socio-economic setups such as road infrastructure, extension services, dairy records, credit and education which have a greater impact are required to enhance resource use efficiency and reinforce the liberalization policy. This implies that judicious investments in institutional and socio-economic factors through enhancement of public expenditure are required to promote market oriented smallholder dairy in the marginal zones.

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DEDICATION

Special dedication to my wife, Mrs. Kavoi D. Mumo: Your love and faith for this purpose at such a time as this has been edifying. To Enoch Muuo Mutuku my son: I believe this challenge for me to peruse graduate studies has been an illumination and an eye opener for your life in future. To Elijah Wendo Mutuku my baby: I believe your tenacity in prayer for my graduate program will continue to shape your life in future. Thanks.

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ACRONYMS AND ABBREVIATIONS

AEZ	Agro-Ecological Zone
AE	Allocative Efficiency
AI	Artificial Insemination
BLUE	Best Linear Unbiased Estimator
COMESA	Common Markets of East and Southern Africa
DCRP	Dairy Cattle Research Project
DCs	Developed Countries
DEA	Data Enveloping Analysis
DFA	Distribution Free Approach
EAC	East African Cooperation
EE	Economic Efficiency
FDH	Free Disposal Hull
GDP	Gross Domestic Product
GLS	generalized Least Squares
GPS	Global Positioning System
IDB	Improved Dairy Breeds
KCC	Kenya Cooperative Creameries
KDB	Kenya Dairy Board
KENFAB	Kenya National Federation of Agricultural Producers
KRA	Kenya Revenue Authority
LDCs	Less Developed Countries
LIMDEP	Limited Dependent
MFC	Marginal Factor Cost
MLE	Maximum Likelihood Estimation
MRP	Marginal Revenue Product
MWV	Mexican Wheat Varieties
NDDP	National Dairy Development Project
OLS	Ordinary Least Squares
RoK	Republic of Kenya
SCE	Scale Economies
SFA	Stochastic Frontier Approach
SSA	Sub-Saharan Africa
SUR	Seemingly Unrelated Regression
TE	Technical Efficiency
TFA	Thick Frontier Approach
UM	Upper Midland
WLS	Weighted Least Squares

Chapter I

INTRODUCTION

1.1. Global Demand and Supply for Livestock Products

The outlook of livestock consumption and production in the global agriculture indicates a persistent and widespread change, with enormous aggregate impacts creating a veritable livestock revolution (Delgado *et al.,* 1999). The less developed countries (LDCs) have been experiencing a higher demand for livestock products than the developed countries (DCs). The projected milk and meat consumption between early 1990s and 2020 in LDCs is 3.3% and 2.8% compared to 0.2% and 0.6% per year respectively in DCs. Population, urbanization and income growth in LDCs have increased demand for these products. Consequently, they are increasing their consumption from the low levels of the past, and have a long way to go before coming near developed country averages (Delgato *et al.,* 2001). Hence LDCs derive 27% of their calories and 56% of protein from livestock products, while the DCs have averages of 11% and 26% respectively. This scenario can partly be explained by the income elasticity of demand which is positive for livestock products in LDCs and negative in DCs. Thus, livestock products may be considered a normal good in LDCs but it may be an inferior good in the DCs.

Projected supply patterns closely follow consumption patterns. The output levels in LDCs are currently lower than their potential as evidenced by higher livestock production levels achieved in developed countries (Ehui and Shapiro, 1995). They only produce about a fifth of the world's milk and about a quarter to a third its meat even though they rear about two-thirds of the world's livestock. However, by 2020, 52% of the world's milk and 60% of the world's meat will be produced in developing countries, contributing to alleviation of poverty and malnutrition and providing sustainable opportunities for small-scale farmers (Rosegrant *et al.*, 2001). Dairy generates 60% of the total household income in the LDCs (Delgado *et al.,* 1999) contributing substantially to livelihoods in these countries. It also contributes to sustainable agriculture by providing manure for fertilizer and fuel (Winrock International, 1992). Ultimately, it enhances household food security.

The rapidly growing demand for livestock products is a rare opportunity for smallholder farmers to benefit from a rapidly growing market. It presents a formidable production challenge for the smallholder dairy farms in Sub-Saharan Africa to meet demand (Thorpe *et al.,* 2000). To exploit these market opportunities for dairy products, it will require continued expansion of specialized dairy cattle; increased levels of inputs (nutrition and health care) matched to good market linkages for milk sales and input acquisition. Along with favourable agro-ecology, these market factors play the major role in determining the type of dairy breeds and production systems found in the tropics, and they will continue to be important influences on smallholder dairy development in the Eastern and Southern Africa.

Kenya is one of the few countries in Sub-Saharan Africa which has developed dairy herds to enhance supply of dairy products in the region. The country dominates dairy production and marketing in Eastern Africa, with over 85% of the dairy cattle population in the region (Thorpe *et al.,* 2000). Since dairy cattle populations in Southern African countries are relatively small, Kenya has over 70% of the population in the Sub-Saharan Region. As a result, the annual per capita milk availability in Kenya is four to seven times higher than the other countries in the region (Thorpe *et al.,* 2000). Kenya was chosen for this study because it has established dairy production in the marginal zones, which form a large area of the Sub-Saharan countries.

1.2. Establishment of Exotic[1] Dairy Breeds in the Marginal Zones

Exotic dairy cattle were first introduced in Kenyan highlands from Europe by European settlers almost a century ago (Conelly, 1998; Omore *et al.,* 1999). They were then placed on high potential areas of Kenya (Figure 1) with temperate climate similar to European climate suitable for these cattle. These areas where also close to urban areas for ease of access to markets. After independence in 1963, European settlers who opted to leave the country sold their large scale farms to Africans or to the government. Many of these farms where sold to African smallholders resulting in a rapid expansion of smallholder[2] herds (Thorpe *et al.,* 2000). Between 1960 and 1998, the proportion of dairy cattle dropped from 88% to 23% in large scale farms and increased from 12% to 77% in small-scale farms (Bebe, 2003). Currently, most of the Kenya's 3 million dairy cattle are kept in smallholder agricultural areas in high potential zones. The exotic and/or improved dairy breeds (IDBs) are the pure Friesian-Holstein, Ayrshire, Guernsey, Jersey and Crosses (Muriuki, 2002). In the current study, all the pure high grade and dairy cross breeds together were termed as the IDBs.

The high potential zones cover about 11% of the land surface in Kenya (Figure 1.1). Land sizes in these traditional dairy keeping areas have been continuously declining due to intergenerational subdivision of farms driven by the rapid growth in population density (Central Bureau of Statistics, 2001). Also, since the development of the smallholder dairy in high potential zones, there has not been a major technological advancement to enhance dairy productivity, continued growth and development of the sub-sector (RoK, 1980).

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1 Holstein Friesian, Ayrshire, Guernsey and Jersey dairy breeds which originated in Europe.

2 Farmers with an average of 4 and a range of 1 to 24 dairy cows (Kilungo, 1999).

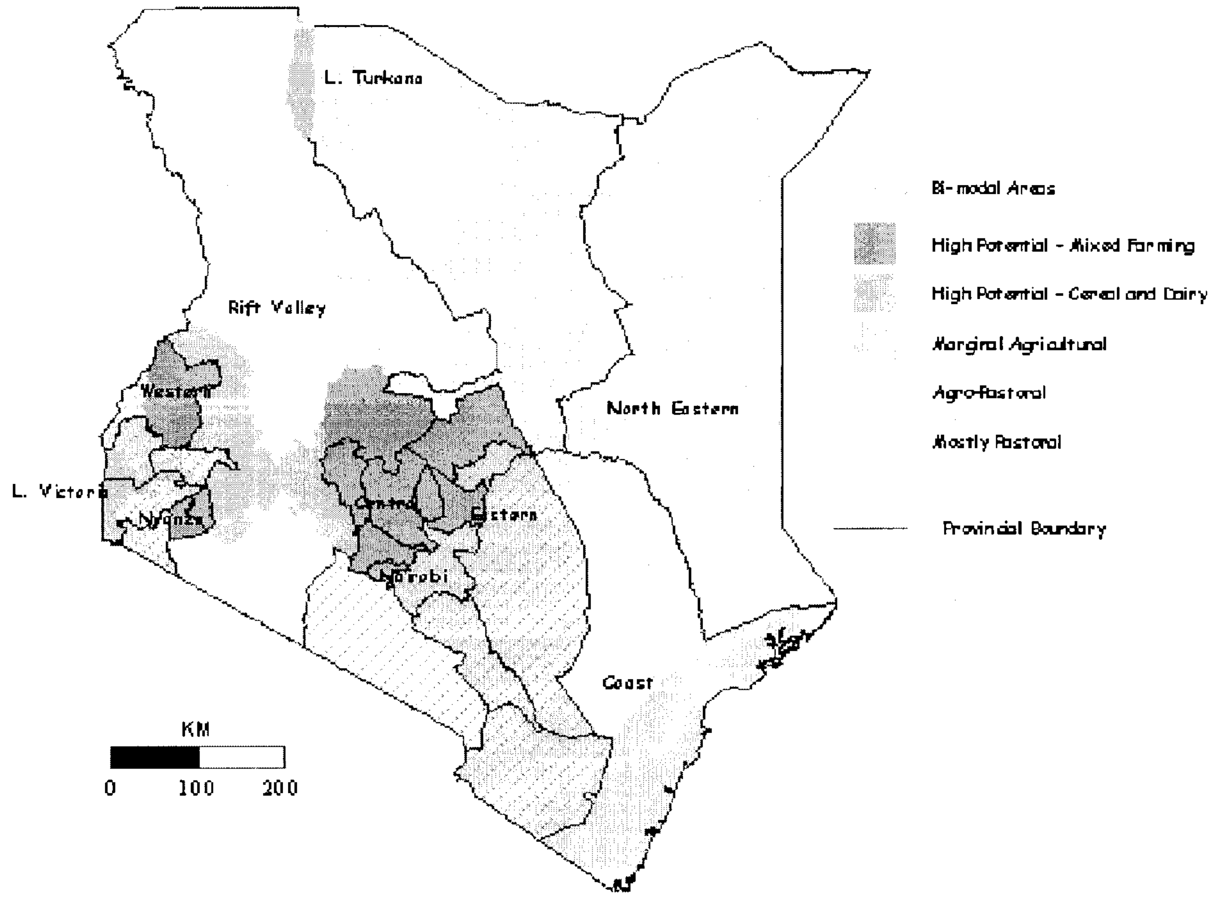

Figure 1.1: High, Medium and Low Potential Agricultural Areas of Kenya

The scope for increasing dairy production in the country has been through horizontal expansion to the marginal lands and dairy technology transfer and adoption in the coastal lowlands and Western Highlands. However, as the country's population pressure on land increases, any new growth in dairy production will be based on improved efficient production in the marginal lands coupled with some capital investments to transform these areas to zones of high-value dairy production (Ngigi, 2005).

The marginal potential zone covers approximately 9% of Kenya's land surface and the rest of the land mass (80%) is a low potential area (Figure1). Since 1980s, there has been an increasing horizontal expansion of dairy cattle through technology diffusion of exotic breeds from the high potential zones to the marginal potential zones. Through the process of acclimatising exotic dairy breeds and some modification of the farm environment (Trail, and Gregory, 1981), these breeds have become accustomed to the marginal zones. In addition, animal scientists have judiciously come up with upgraded cross breeds suitable for these areas; once hypothesized that the "drier marginal zones" could not meet the requirements of the high performing exotic breeds. And that improved zebu breeds with lower nutritive requirements and greater adaptability to marginal conditions, would be more suited to the marginal and semi-arid environments, even though their production response capability is relatively low (Meyn and Wilkings, 1973; Kimenyi and Russell, 1975). Currently, exotic breeds, which were considered alien to the marginal environments in the last two decades, are now available and smallholder farmers have formed dairy cooperative societies to enhance milk marketing (Republic of Kenya, 1985-2003). Indications are that smallholder farmers in the marginal zones are now recognising that IDBs have considerable potential to increase milk production beyond subsistent requirements, given the resources available (Kamau, 1977).

As observed by Traxler (1990) three important levels of analysis arise when widespread farmer adoption and use of a productive new technology is established. One is to link adoption of new technology with improvements in the welfare of farm households and rural villages. The second issue concerns the question of efficiency and the profitability of the new technology. Furthermore, assessment of the impact of new technology can not end with the adopting farm households. Impact on non-adopting population (e.g. consumers) mediated through product prices and wage rates may be equally important. A few studies on adoption of dairy technologies in Kenya have grappled with the first issue.

Nicholson *et al.,* (1998, 2004) analysed household-level impacts of dairy cow ownership in an adoption study in the coastal region. Staal *et al.*, (2002) compared adoption of dairy technologies in the Kenya highlands by use of pooled data across Kenya, and Batz (2000) studied adoption of dairy technologies in Meru region. The task in this study is to attempt to provide an answer to the second question. It will determine the economic performance of IDBs in the marginal zones, the emerging production structure and the supply response of the smallholder dairy farms in a liberalized market environment.

1.3. Problem Statement

Kenya's Dairy experts in 1970s argued that the "dry marginal zones" could not meet the requirements of the high performing exotic breeds (Meyn and Wilkings, 1973; Kimenyi and Russell, 1975). They recommended that upgraded zebu breeds, which have a lower nutritive requirements and greater adaptability to marginal conditions, would be more suited to the marginal and semi-arid environments, even though their milk supply response capability is relatively low. The livestock improvement efforts focused on crossbreeding initiatives that attempted to exploit the considerable flexibility inherent in matching complimentary breed types to local environmental resources and constraints (Gregory and Cundiff, 1980). This led to a frequent extension recommendation for smallholder systems to adopt and use small sized dairy breeds (Bebe *et al.*, 2003). The use of larger breeds and /or upgrading to high exotic grades is generally discouraged by dairy experts and the livestock extension service because of their higher nutritional demand, low milk yield, poor adaptability and perceived low production performance under smallholder management conditions (Rege, 1998; Kahi *et al.*, 2000; Wakhungu, 2000). It is argued that the potential performance of these larger breeds cannot be maximized under the small-scale management regime in the marginal zones.

The smallholder farmers have often not followed the extension recommendation given and have instead shown preference for high grade breeds as a key component of their improved milk production strategies (Bebe *et al.*, 2002; Devendra, 2001; Tulachan *et al.*, 2000). Their practice of upgrading indigenous zebu breeds has mainly targeted improvement to higher exotic grades without a defined breeding program and disregarding the ecological and socio-economic characteristics of the production systems. Even though results from several dairy science studies discourage the use of high grade breeds, the contrary has continued to be observed (Syrstad, 1996; Rege, 1998; Wakhungu, 2000).

The research problem statement is the continued establishment of high exotic grade dairy in the marginal zones, in spite of their potentially low economic performance in such relatively hostile dry areas and a volatile agricultural policy environment in the last two decades. Smallholder farmers in the marginal zones have experienced profound technical, economic and increasingly changing policy environment in the recent past. In such a dynamic system, farmers find it more difficult to adjust allocation decisions to keep pace with changes in their environment and at the same time, maintain an efficient allocation of resources (Ali and Byerlee, 1991). The combination of an evolving technical, economic and policy environment means that the equilibrium required for economic efficiency is a constantly moving target. Farmers in this situation are likely to be in a continual state of disequilibrium, and there will be high returns to improving their information and skills to help them to adjust more rapidly. In this new scenario, the scope for inefficiencies in resource use is much greater and hence development strategy may need to be re-examined. This study therefore examines the performance of dairy establishment and the possibilities of expansion in the marginal zones.

Although considerable efforts have been directed at transfer, adoption and use of IDBs in the marginal zones, little or no attention has been given to the relationships between efficiency of high grade dairy breeds, improved dairy herd attributes, market indicators and household characteristics, the emerging structure of production and supply response. An understanding of these relationships could provide the policy-makers with information to design programs that can contribute to measures needed to expand dairy production potential in the marginal zones of Kenya. The production structure and supply response would permit measurement of the different impacts that exogenous variables have within and across input demand and milk output supply relationships. Therefore, the purpose of this study is to determine the economic performance of the smallholder exotic dairy breeds, the associated production structure and supply response in the marginal zones. To achieve the objectives of the current study, three interrelated approaches to production analysis are employed. The first approach uses the stochastic frontier framework to determine the dairy farm; household and socio-economic attributes that influence cost inefficiencies and estimate their impacts. In the second and the third approaches, dairy production structure and supply response are analysed using the systems approach framework which permits measurement of different impacts that exogenous variables have within and across dairy input demands and milk supply .

1.4. Purpose and Goals of the Study

The main purpose of this study is to enhance economic performance measured through efficiency, production structure and supply response of smallholder dairy farms in the marginal zones of Kenya and to improve the opportunities and the welfare of farmers in the region. The study has three main goals:

i) To determine economic efficiency of dairy farmers and identify the institutional and socio-economic factors that influence efficiency of dairy practices in the marginal zones.

ii) To determine the production structure and input substitution in dairy production in the marginal zones.

iii) To determine the supply response of dairy farmers in the marginal zones.

1.5. The Study Area

The study area consists of Machakos and Makueni Districts as shown in Figure 1.2. Several reasons led to the choice of these two districts for the study. First, they constitute the main marginal and transitional districts of Kenya besides Kitui District, and Kilifi and Kwale hinterland in the coastal region (see Figure 1.1). Second, exotic dairy production is fairly established in these districts and the majority of smallholder producers have organized themselves into dairy cooperatives making it convenient to sample farmers using co-operative registers. Third, the establishment of smallholder dairy industry in the two districts has followed a slightly different path from that currently being used in Kitui and the Coastal region.

Establishment of dairy in Machakos and Makueni districts has been as a result of a slow process of technology diffusion from high potential zones, with minimal national livestock extension service involvement. However, in Kitui and the Coastal region, dairy is being established through judicious means of technology transfer and adoption

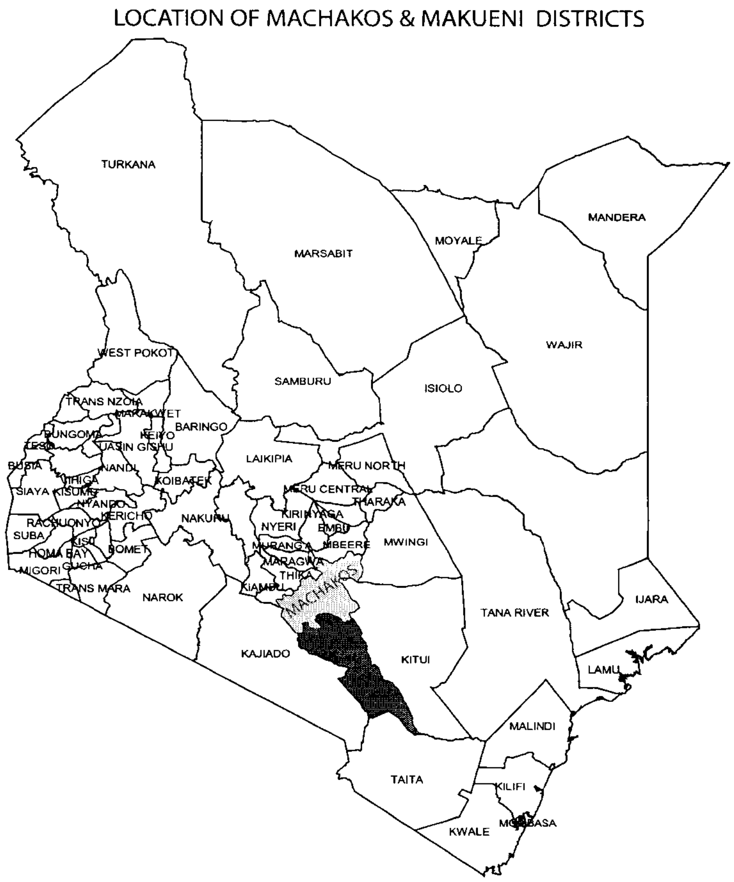

Figure 1.2: Location of Machakos and Makueni Districts in Kenya (Shaded).

resulting from a concerted joint effort of the government and development partners. Fourth, small scale dairy farmers in the marginal zones and the transitional semi-arid lands are often neglected in policy making and in the planning of extension and dairy development programs. For example the Dairy Cattle Research Project (DCRP) was a nationwide project (1969-1976) with an objective of disseminating dairy technologies to large scale farmers in the high potential areas where dairy industry had already been established. In 1980s, the National Dairy Development Project (NDDP) was established with an objective of disseminating dairy technology to small-scale farmers. The technology was a zero-grazing package that was attractive where land was scarce and farm sizes small. The NDDP covered 25 districts in central province, rift valley province, South Nyanza, and coast province in Taita Taveta and Kilifi Districts. It effectively locked out the dairy farmers in the marginal and semi-arid districts. Ultimately, due to lack of national attention compared to the high potential areas, the constraints and the production potential of the marginal zones are rarely investigated and understood even by the professionals. This study therefore highlights the establishment of the dairy industry in the Marginal zones to the policy makers and researchers, with a view to developing suitable interventions to enhance dairy expansion and growth in these areas.

The marginal and transitional zones of Machakos and Makueni Districts have a warm and dry climate. They are characterized by a bi-modal rainfall pattern with a mean annual rainfall ranging between 625 mm and 850 mm and an altitude starting from 1,000 to 1,900 m above the sea level. Most crop production is undertaken during the October-February short rain season which accounts for approximately 70 percent of the total annual agricultural production (Republic of Kenya (RoK), 2002). Rainfall reliability during the March-May long rain season is low and frequently results in drought and crop failure worsening the food security situation in the region (Mbithi, 1999).

Agriculture provides employment to the majority of the people in the marginal districts (RoK, 2002). But it is unreliable and food deficits are often experienced. Crop farming is mainly for subsistence purposes with occasional sales of the surplus production when realized. The major food crops grown are maize, beans, pigeon peas, and cowpeas. There are no established cash crops in the marginal zones compared to the high potential areas where industrial cash crops such as tea, coffee and pyrethrum are grown. Neither is there off-farm employment activities such as tourism and fishery industry like in the coastal areas of Kenya, where labor allocation to cattle by household members decreases due to off-farm employment and labor requirements for dairy cows are met primarily by an increase in hired labor (Nicholson *et al.*, 2004). Household incomes in the marginal zones are therefore low (RoK, 2002). The population of Makueni and Machakos Districts in 1999 was 771,545 and 906,644 respectively (RoK, 2005). However, 73.1% and 63.3% of the population in Makueni and Machakos respectively live below the poverty line[3] (RoK, 2000). Hence, reduction of poverty remains one of the greatest challenges in the marginal zones.

The import of dairy industry in the marginal and Semi-Arid lands of Kenya therefore cannot be overemphasised. Alternative new agricultural activities which offer higher returns to land and labour, offer the expectation of future growth, and are suitable for the resource poor smallholder farmers who continue to dominate agricultural production are needed (Nicholson *et al.*, 2004). Market oriented dairy production has filled this need for smallholder producers in the marginal zones. Smallholder farmers in these areas have been compelled by policy changes and markets to diversify from traditional subsistent staple food crops whose outlook for growth remains uncertain, to cash market oriented smallholder dairy production. The challenge for the transition to the next stage is to intensify dairy production and achieve the greatest possible output given the available resources and the new dairy technologies.

Intensification of dairy production involves the use of exotic cattle breeds which have increased genetic potential for milk production and other complementary inputs which can have several potential avenues for impact (Nicholson *et al.*, 2004). In a number of regions, there is good potential for increased demand and higher real prices for milk and

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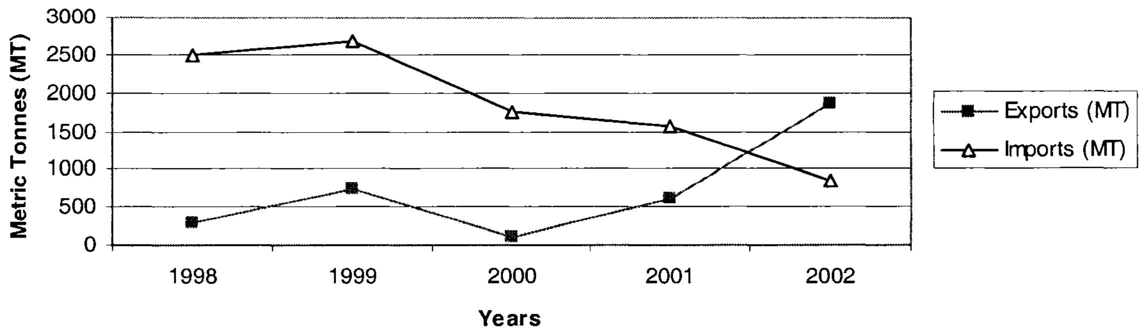
[3] People who earn below Kshs.1238.86 ($17.21) per month (RoK, 2000).

dairy products especially in the urban areas of Makueni, Machakos and the neighbouring districts in the marginal zones. It can result in increased incomes for smallholders. Cash receipts from milk and dairy product sales typically are distributed more evenly throughout the course of a year. Where there is regular payment from milk societies, cash receipts constitute a monthly salary in an area where there are no cash crops. Because dairy production tends to be labour intensive, it can increase the intensity of household labour use and generate hired employment. This may stimulate the demand for labour, providing benefits to unskilled labourers and distributing the gains from dairy production more broadly and progressively (Nicholson *et al.*, 2004). Thus, smallholder dairy production is a catalyst for agricultural development. It has the potential to increase income generation and employment with subsequent enhancement of food security and improvement of livelihoods (Winrock International, 1992).

Staal (2002) illustrates the competitiveness of dairy through a case study in two areas in Kenya showing extensive and intensive dairy. The intensive smallholder dairy gets above normal profits, indicating that it is quite competitive amongst other farming enterprises. Thus, the competitiveness of smallholder dairy is unchallenged. However, the challenge is to formulate tailored interventions that would increase intensification in the marginal zones. Research should identify the bottlenecks in smallholder dairy production in these areas and this is one such study. The motivation for this study, it will be recalled, is to enhance the efficiency of smallholder dairy farms in the marginal zones of Kenya and to improve the opportunities and the welfare of farmers in the region.

1.6. Dairy Economics and Policy in Kenya

The livestock sector is important to the Kenyan economy. It contributes 10% of the overall Gross Domestic Product (GDP), and 30% of the agricultural GDP (Omore *et al.*, 1999). Livestock products constitute 19% of the marketed agricultural produce, and 12% of the marketed livestock products is dairy (RoK, 2003). The dairy sub-sector contributes 3.5% of Kenya's GDP (Kiptarus, 2005). Production statistics indicate that Kenya is occasionally a net exporter of dairy products and sometimes a net importer (Kilungo, 1999). During the early 1970s, Kenya was a net exporter but through most of the 1980s large quantities of powdered milk had to be imported. In 1988, there was once again a surplus of domestic supplies and records indicate that Kenya exported 1913 Metric Tons of powdered milk. Since 1989 and the whole of the last decade there was an insignificant amount of external trade bordering on imports of processed powdered dairy products (Figure1.3).



Source:CBS Statistical Abstract, 2003.

Figure 1.3 Export and Import Quantities (MT) of Dairy Products in Kenya 1998-2002.

Policy and weather were cited as the major constraints to production and supply of dairy products during this period. In the current decade, Kenya has been exporting dairy products such as liquid milk, cream, butter and ghee in the regional markets i.e. Zambia, Tanzania, Uganda, Democratic Republic of Congo, Rwanda, Burundi and Saudi Arabia among other countries (RoK, 2005). But concerns exist as to the ability of the dairy industry to confront the challenges presented by the highly competitive export environment (Gamba, 2006). One of the available channels to confront increased competition in the dairy industry is by developing a vibrant and efficient dairy production system which ultimately would result in lower production costs.

Kenya's stated policy is to increase production in the dairy sub-sector by promoting competition and efficiency through liberalization (RoK, 1994). Several of the past policy papers (RoK, 1986, 1988 and 1994) point out that potential for self-sufficiency in livestock production exists. The specific strategies spelled out in various livestock development documents include: expanding the dairy herd, increasing the milk yield per cow per lactation and a more competitive dairy production and marketing system. The current trend in the livestock industry particularly dairy and beef is more inclined towards tapping the opportunities presented by the export markets (Gamba, 2006), especially the East African Cooperation (EAC) and the Common Markets of East and Southern Africa (COMESA). To realize the existing output potential, and meet the policy targets and challenges in the dairy industry, productivity gains will be based on more efficient resource use patterns enhanced by changes in the institutional and the policy environment (Ali, 1995).

Equitable and efficient agricultural production and marketing are vital for rural development. In many of the past policy papers, the government of Kenya has recognized the importance of efficient production and remunerative prices to agricultural producers and adequate supply of quality products to consumers (RoK, 1980, 1981, 1986, 1988 and 1994). To ensure maximum welfare of all producers and consumers, production and marketing costs should not be unnecessarily high. This necessitates investments in public goods such as physical, institutional and social infrastructure to enhance the performance of production and marketing systems. Such improvements in the marketing systems can contribute to both economic and agricultural development (Eicher and Baker, 1990). In developing countries however, market failures are prevalent or markets are incomplete and producers and consumers respond to economic signals and incentives that are a poor reflection of the "real" cost to society of goods, services and resources (Todaro, 1985). In the absence of effective market structures, efficient production and marketing systems cannot be expected to evolve automatically and that at some stage government intervention to stimulate the development of effective internal production and markets may become crucial especially to rural development. Kenya has a well developed dairy production and processing industry compared to other Sub-Saharan African (SSA) countries. This has been attributed in part to government interventions that promoted the expansion of smallholder dairy production after independence. To enhance dairy development, the government affected a number of incentives in the provision of milk production and marketing services. In 1966, subsidized services were introduced including clinical and daily runs to provide artificial insemination. In 1971, the government abolished the contract and quota system of dairy marketing to Kenya Co-operative Creameries (KCC) because it had effectively excluded most smallholder producers from delivering milk. Subsidized dairy services continued up to the advent of market reforms early in 1980s. Inadequate government budget allocations caused the quality of services to decline as subsidization became increasingly unsustainable. This prompted the government to restructure the industry with a view to increasing the role of the private sector (Omore *et al.,* 1999). During the past decade, the dairy industry in Kenya has undergone substantial liberalization with the markets being subjected to the forces of supply and demand much more than formerly. It is hoped that liberalization will foster efficient allocation of resources thereby increasing both producer and consumer welfare. To achieve net social benefits, the market must be efficient.

In the last decade, a major policy change to take place in the dairy sub-sector is the policy of price decontrol of milk markets in 1992 (RoK, 1993), which effectively ended the monopoly of KCC in milk processing and distribution in the urban and rural areas and stimulated increased small-scale trading in fresh milk (Owango *et al.,* 1998). The government also started licensing cooperatives to undertake milk marketing. The provision of animal health and breeding services was fully decontrolled in 1994 (Omiti, 2002). The major impact of the dairy industry liberalization policy has been a rapid growth of the formal and informal private sectors that provide input and output services in a competitive market oriented dairying to smallholder producers, market agents and consumers in Kenya. Key to understanding milk production in Kenya is the recognition of the role of the informal or raw milk marketing. It is estimated that about 80 per cent of marketed milk is neither processed nor packaged, but is bought by the consumer in raw form (Omore *et al.*, 1999), mainly due to traditional preferences for fresh raw milk, and to the unwillingness of resource poor consumers to pay the costs of processing and packaging. On the input side, dairy farms are dependent on livestock services such as clinical veterinary services and artificial insemination (AI), critical to maintaining the health of susceptible dairy breeds and the genetic potential for higher milk yields (Staal *et al.,* 2002). After liberalization, the government has reduced support to AI and veterinary services. It is important to note that expected replacement of these public services by private entrepreneurs has only partially occurred, and then only in high cattle density areas e.g. high potential zones where demand is adequate to support them.

The liberalization policy of the dairy industry was met with mixed reactions from various stakeholders. Some groups felt that price decontrol would improve the welfare of both producers and consumers. Others felt that the emergence of the informal sector which handles 80% of marketed milk was quite unintended because it sells raw milk; posing a major health hazard threat to the consumers (Omore *et al.*, 1999). The government's position was that price decontrol would promote efficient allocation of resources thereby increasing both producer and consumer welfare, ensure timely payments & adequate returns to producers and ultimately attract private investments in the dairy industry. Studies in Kenya's dairy sector had identified price regulation as an important obstacle to improved performance of the sector (Ruigu, 1978; Omiti 1989).

Economic reforms implemented in many developing countries during the last two decades have major implications for the dynamics of the socio-economic and institutional environments within which farmers operate. The reforms have been justified as a means through which farmers can enhance their economic efficiency thereby spurring higher agricultural productivity (Karanja, 2002). Since the unfolding process of agricultural and economic reforms began, there has been a dearth of empirical studies documenting the level of agricultural production efficiency in Sub-Saharan Africa. Equally, the relationship between market indicators, household characteristics, institutional factors and production efficiency has not been well understood. In addition, analysis of different impacts across input demands and output supplies of the various agricultural sub-sectors in a liberalized market environment have received no attention so far. An improvement in the understanding of the levels of production efficiency, its relationship with a host of farm level factors coupled with insights of the output supply response can greatly aid policy makers in creating efficiency-enhancing policies as well as in judging the efficacy of the present organization of production. For individual farms, gains in efficiency are particularly important in periods of financial and economic stress similar to what is frequently experienced by farmers in the marginal zones. The efficient categories of well organized farms are more likely to generate higher incomes and thus stand a better chance of surviving and prospering in a relatively hostile marginal environment which experiences rainfall failures, drought and high animal disease incidences.

In recent years, there have also been important methodological developments in measuring economic efficiency and supply response that provide better empirical estimates of levels of efficiency, production structure and supply response. These new methodologies need to be tested in more diversified farming situations than currently is the case. A review of production efficiency literature indicated that most of the studies done to estimate farm inefficiencies have been undertaken in Asia (Ali and Byerlee, 1991; Ali and Flinn,1989; Battese, 1992; Rahman, 2003). Very few past studies (Kibaara, 2005; Karanja, 2002) have been undertaken in Kenya. Even in Kenya, those available mainly targeted the high potential areas and none is reported to have been undertaken in the drier marginal zones. Owing to major climatic, economic and institutional differences, efficiency evidence from the high potential zones of Kenya may not be directly applied in the formulation of agrarian and livestock policies in the drier marginal zones. This study, therefore, hopes to contribute towards better understanding of economic efficiency of smallholder exotic dairy cattle, the associated production structure and the supply response in the marginal zones of Kenya.

1.7. Outline of the Dissertation

This dissertation follows an outline consistent with the objectives set out in section

1.4. Following this introduction, Chapter Two presents a survey of literature on the analytical procedures applied in this study. It presents an overview of each analytical procedure and its conceptual framework in relation to production economic theory. Literature is reviewed on prior studies utilizing each analytical model and how it relates to the current study. The conclusion and the justification of the study are discussed. The chapter closes with highlights on the contribution and limitations of the current study. Chapter Three reviews the theoretical considerations and research methodology of the study. It discusses the assumptions, the theoretical basis, the econometric specifications and the hypotheses testing of the analytical procedures applied. The data collection method and types of data collected for empirical estimation of the analytical models are also detailed in this chapter. It then closes with a discussion of the descriptive statistics and the Global Positioning System (GPS) map of the study area.

Chapters Four, Five and Six form the core of this dissertation. Chapter Four analyzes and documents the factors influencing cost inefficiency of smallholder dairy production in the marginal zones. The results on factors causing inefficiencies are discussed. It then presents conclusions and recommendations. Finally, it discusses the policy implications. Chapter Five delineates the factors influencing costs of dairy production and the factors impacting on input demands. It presents the results on input demand share elasticities, the Morishima elasticities of substitution and scale elasticity. The results are discussed as well as the conclusions and recommendations. The chapter closes by discussing the policy implications. Chapter Six determines the supply response of dairy production in the marginal zones. It presents the results and their discussions. Conclusions and recommendations are presented. It then closes by discussing the policy implications arising from the results. Chapter Seven presents the general discussions and conclusions. It gives the overall summary and the implications of the study. The results of the three approaches to dairy production analysis are compared. A summary of policy implications are presented. The chapter then closes by pointing out areas for future research.

Chapter II

SURVEY OF LITERATURE

2.1. Introduction

After exotic dairy cattle with European germplasm, were introduced into Kenya by colonial settlers, smallholder dairy production has been adopted in the marginal, Coastal lowlands and Western region through technology diffusion and transfer over time. Most studies have focused on Kenyan highland areas because dairy cattle ownership is more prevalent among smallholders in this zone. Relatively few studies based on dairy technology adoption have been done in the coastal lowlands (Nicholson, 1998; 2004) and Western region (Makokha, 2006) and none so far in the marginal zones. There is therefore an information gap on the performance of established smallholder dairy farms in marginal areas of Kenya that this study made an effort to fill.

This chapter develops a conceptual framework that is based on the theoretical foundations of production economics and emphasizes on economic efficiency, production structure and supply response to determine the performance of exotic dairy cattle in the marginal zones. It starts with an overview of economic efficiency in Section 2.2, followed by the conceptual framework in Section 2.2.1, and prior studies utilizing the stochastic frontier approach in Section 2.2.2. Section 2.3 presents an overview of supply response and production structure. The conceptual framework of supply response and production structure is discussed in Section 2.3.1. Prior studies on production structure are reviewed in Section 2.3.2. Section 2.3.3 discusses prior studies on the supply response. Section 2.4 presents the conclusions and the justification of the study. Finally, Section 2.5 closes the chapter by discussing the contribution and limitations of the current study.

2.2. Overview of Economic Efficiency

The level of efficiency of small farmers has important implications for development strategy. If farmers are reasonably efficient, then increases in productivity require new inputs and technology to shift the production function upwards (Ali and Byrerlee, 1991). On the other hand, if there are significant opportunities to increase productivity through more efficient use of farmers' resources and inputs with current technology, a stronger case can be made for institutional investments in input delivery, infrastructure, extension systems, farm management services and farmers' skills in order to promote efficiency of resource use at the farm level (Ali and Byrerlee, 1991). In practice, technology development and transfer versus more efficient use of available technology and resources at the farm level are likely to be a continuum in the development process.

In some of the developing countries such as Kenya, agriculture is newly liberalized and is characterized by dynamic changes in technical, economic and policy environments which farmers find more difficult to adjust allocative decisions to keep pace with changes in their environment and, at the same time, maintain an efficient allocation of resources (Ali and Byrerlee, 1991). These farmers are likely to be in a continual state of disequilibrium. The combination of evolving technical, economic and policy environment means that the equilibrium required for economic efficiency is a constantly moving target. Also, efficiency is now viewed more in terms of a system performance, including farm characteristics, socioeconomic and institutional factors rather than focusing narrowly on farmers' rationality. In line with this modern concept of efficiency, interest centers on system inefficiencies that cause resource productivity to be below their potential. Economic efficiency has also a dynamic context in that introduction of new technologies and inputs and market reforms that shift the level of relative prices, can cause a destabilization of allocation of resources thus creating temporal inefficiencies. There is therefore need to determine the level of economic efficiency for the smallholder dairy establishment in the marginal zones, and the possible factors constraining its expansion.

2.2.1. Conceptual Framework of Economic Efficiency

Following the pioneering work of Farrell (1957), economic efficiency is disaggregated into two components: technical efficiency (TE) and price or allocative efficiency (AE). Technical efficiency refers to the ability of a farm to obtain the maximum possible output from a given set of resources and technology. Technical efficiency is therefore the ability of farm households to avoid waste by producing as much output as input usage allows or by using as little inputs as output production requires. On the other hand, allocative efficiency generally refers to a firm's ability to maximize profits, by equating the marginal revenue product (MRP) with marginal factor costs (MFC) of inputs. Thus, allocative efficiency refers to the farmer's ability to combine inputs in optimal proportions given the prevailing set of prices (Fried *et al.*, 1993). In Farrell's framework, economic efficiency (EE) is an overall performance measure and is equal to the product of TE and AE (i.e. EE= TE* AE).

Technical efficiency is usually statistically estimated through production functions or through programming models that estimate the best output for comparison with an average or individual farmer's output. Allocative efficiency is, however, determined by comparing the marginal products of factors with their normalized prices.

Following Farrell (1957), a host of models-collectively known as frontier models have been developed. These models can further be classified into parametric and non-parametric models depending on their specific functional forms (Försund *et al.*, 1980; Fried *et al.*,1993). The non-parametric approach is composed of the data enveloping analysis (DEA) and the free disposal hull (FDH). The parametric approach is composed of the stochastic frontier approach (SFA), the thick frontier approach (TFA) and the distribution free approach (DFA). These methods differ mainly in the assumptions made about the functional form, whether or not random errors have been accounted for, and the probability distribution assumed for the inefficiency. Another important distinction is between deterministic and stochastic frontiers. The deterministic models assume that any deviation from the frontier function is due to inefficiency. The stochastic approach allows for statistical noise (Thiam *et al.*, 2001). However, there is no consensus among researchers as to the best method for measuring efficiency.

The stochastic frontier models are the most commonly used to study production efficiency. Bauer (1990) argues that there are two competing paradigms about the construction of frontiers i.e. mathematical programming and econometric technique. The main advantage of mathematical programming or DEA approach is that no explicit functional form is needed to be imposed on the data. Färe *et al.* (1994) have comprehensively discussed these methods. However, most mathematical models belong to the deterministic type which have been characterised by sensitivity to extreme observations and non-composed error term. To overcome the extreme observation problem, Aigner *et al.* (1977) and Meensen and Van den Broeck (1977) independently developed the stochastic frontier model.

The stochastic frontier incorporates a composed error structure with a two-sided symmetric and a one-sided component. The one sided component reflects inefficiency while the two-sided component captures random effects outside the control of the production unit including measurement errors and other statistical noise typical of empirical relationship (Aigner *et al.,* 1977; Meedsen and Van den Broeck, 1977). An extension of the stochastic frontier model by Jondrow *et al.* (1982) solved the previous inability of deriving individual firm inefficiency measures.

The production technology can be represented in form of cost and profit functions. The cost and profit function represent the dual approach in that technology is seen as a constraint towards the optimizing behaviour of firms (Chambers, 1983). In the context of cost or profit function, any error of optimization is taken to translate into higher costs or lower profits for the producer. The stochastic nature of the production frontier would in addition imply that the theoretical minimum cost and maximum profit frontier would also be stochastic.

According to Lau & Yotopoulos (1971) and Ali & Flinn (1989), a production function approach may not be appropriate when estimating efficiency of individual farms due to differences in prices and factor endowments. As such, estimation of efficiency should incorporate farm specific prices and levels of fixed factors as variables in the analysis. Where there is a major variability of input and output prices as is expected in the liberalized dairy industry in Kenya, the use of the dual models in estimating efficiency is expected to give superior results. Furthermore, the use of dual forms of production technology can also enable the simultaneous prediction of both technical and allocative efficiency.

Given the exposition above, this study has adopted stochastic cost model to estimate the cost inefficiencies in smallholder dairy farms in the study area. The dual models are preferred because smallholder farmers in the marginal zones are expected to maximize profits in the prevailing liberalized market oriented dairying environment. The profit function approach has problems of estimation that may arise in situations where farm households realize zero or negative profits at the prevailing market prices. Carlos (1991) points out that zero or negative profits can be a major estimation problem as the logarithm of a zero or a negative number is unidentified. Therefore, the coast function approach would be used to estimate cost inefficiencies and to identify farm-specific characteristics that explain variations in efficiency of individual dairy farmers in the study area.

2.2.2. Prior Studies Utilizing the Stochastic Frontier Approach

Stochastic frontier approach has found wide acceptance within the agricultural economics literature because of their consistency with theory, versatility and relative ease of estimation. The measurement of economic efficiency (technical, allocative and scale) has remained an area of important research both in the LDCs and the DCs. This is especially important in LDCs where there are meagre resources and opportunities for developing and adopting better technologies are dwindling. Efficiency measures are important because it is a factor for productivity growth. Such studies benefit these economies by determining the extent to which it is possible to raise productivity by improving the neglected source of growth i.e. efficiency, with the existing resource base and available technology.

Bravo-Ureta & Pinheiro (1993) and Ali and Byerlee, (1991) provide a comprehensive review of the application of the stochastic frontier models in measuring the efficiency of agricultural producers in developing countries. Most of these studies however, concentrate in measuring technical efficiency; one of the components of economic efficiency.

Awudu and Eberlin (2001) used a translog stochastic frontier model to examine technical efficiency in maize and beans in Nicaragua. The average efficiency levels were 69.8 and 74.2 percent for maize and beans respectively. In addition, the level of schooling represented human capital, access to formal credit and farming experience (represented by age) contribute positively to production efficiency, while farmers' participation in off-farm employment tended to reduce production efficiency. Large families appeared to be more efficient than small families. Although a larger family size puts extra pressure on farm income for food and clothing, it does ensure availability of enough family labor for farming operations to be performed on time. A positive correlation between inefficiency and participation in non-farm employment suggests that farmers reallocate time away from farm-related activities, such as adoption of new technologies and gathering of technical information that is essential for enhancing production efficiency. The result indicated that efficiency increased with age until a maximum efficiency was reached when the household head was 38 years old. The age variable probably picks up the effect of physical strength as well as farming experience for the household.

In a study by Wilson *et al.* (2001) a translog stochastic frontier and joint estimate technical efficiency approach was used to assess efficiency. The estimated technical efficiency among wheat producers in Eastern England ranged between 62 and 98 percent and found farmers who sought information, and had more years of managerial experience and with large farms, were associated with higher levels of technical efficiency.

Belen *et al.* (2003) made an assessment of technical efficiency of horticultural production in Navarra, Spain. They estimated that tomato producing farms were 80 percent efficient while those that raised asparagus were 90 percent efficient. Therefore, they concluded that there exists a potential for improving farm incomes by improving efficiency.

Kibaara (2005) analyzed the technical efficiency in Kenya's maize production using a translog production function. The results indicate that maize farmers are 49 percent efficient with a range of 8 to 98 percent. There is also a distinct intra and inter-regional variability in technical efficiency in the maize producing regions. In addition, technical efficiency varies by cropping system; the mono-cropped maize fields have a higher technical efficiency than the intercropped maize fields. The number of years of formal schooling, age of household head, health of the household head, gender of the household head, use or non use of tractors and off-farm income impact on technical efficiency.

The popular approach to measure efficiency, the technical efficiency component is the use of stochastic frontier production function. The above studies and several others (see Bravo-Ureta and Evenson, 1994; Battese and Coelli, 1995; Battese *et al.*, 1996; Liu and Zhuang, 2000; Seyoum *et al.*, 1998; Wilson *et al.*, 1998) have used the frontier production function to study technical efficiency in agriculture. Several other studies in Kenya have used average production function (Murithi, 1990; Mwangi, 1981, and Ruigu, 1978) or average profit function (Kilungo, 1999) to study economic efficiency of dairy production. Some additional studies in Africa have also used average profit function (Saleem, 1988; Adesina & Djato, 1997) to evaluate the efficiency of resource use in crop agriculture. However, the use of the production frontier to measure technical efficiency is limited because it does not take into account input and output prices in the analysis of efficiency. Therefore, it may not be appropriate for estimating the economic efficiency of individual farms because they may face different prices and have different factor endowments (Ali & Flinn, 1989). Average profit functions can be used to determine relative efficiency between farm groups (Lau and Yotopoulos, 1971). But, average profit function models do not provide a numerical measure of farm-specific efficiency (Aigner *et al.*, 1977). As a result, Yotopoulos and Lau, (1979) argue that the estimation of efficiency should incorporate farm specific prices and levels of fixed factors as arguments in the analysis. This led to the application of dual models in stochastic frontier formulations to estimate farm specific efficiency directly as reviewed below.

Ali and Flinn (1989) used a two-step approach to estimate farm specific profit inefficiency among Basmati rice producers from a variable-coefficient profit frontier. They used a stochastic translog profit model for the analysis. The mean level of inefficiency at farm resources and price levels was 28 percent, with a wide range of 5 to 87 percent. Average loss of profits was Rs 1,222 per hectare. Socioeconomic factors related to profit loss were the farm household's education, non-agricultural employment, and a credit constraint. Institutional determinants of profit loss were a water constraint and the late application of fertilizer. Punjab-wide benefits of increasing farmer's profit efficiency were large; a 25 percent reduction in profit loss among Basmati rice producers may generate over Rs 240 million in extra profits each rice season.

Awudu and Huffman (2000) studied economic efficiency of rice farmers in Northern Ghana. Using a normalized stochastic profit function frontier in a two-step approach, they concluded that the average measure of inefficiency was 27 percent, which suggested that about 27 percent of potential maximum profits were lost due to inefficiency. This corresponds to a mean loss of 38,555 cedis per hectare. The discrepancy between observed profit and frontier profit was due to both technical and allocative efficiency. Higher levels of education reduced profit inefficiency while engagement in off-farm income earning activities and lack of access to credit experience higher profit inefficiency. The study also found significant differences in inefficiencies across regions.

Production inefficiency is usually analysed by its three components-technical, allocative and scale efficiency as individual components. However, Rahman (2003) provided a direct measure of production efficiency of the Bangladeshi rice farmers using a stochastic profit frontier and inefficiency effects model. The results showed that there are high levels of inefficiency in modern rice cultivation. The mean level of profit efficiency is 77 percent suggesting that an estimated 23 percent of the profit is lost due to a combination of technical, allocative and scale inefficiency in modern rice production. The efficiency differences are explained largely by infrastructure, soil fertility, experience, extension services, tenancy and share of non-agricultural income.

Gautam and Alwang (2003) used a stochastic cost function to measure efficiency among smallholder tobacco cultivators in Malawi. Their study revealed that larger tobacco farms are less cost inefficient. The paper uncovered evidence that access to credit retards the gain in cost efficiency from an increase in tobacco acreage. This suggested that the method of credit disbursement was faulty.

Karanja (2002) studied production efficiency of farmers in the high potential zones of Kenya. Cross-sectional data on input costs and aggregate output was used to measure farm specific inefficiencies. A two-stage stochastic translog cost frontier model was used to estimate the cost inefficiency levels of smallholder coffee households in central province. The results show that the smallholder farmers in Central Kenya region are quite cost efficient. The average level of cost inefficiency is between 7.9 and 8.5 percent depending on the stochastic distribution assumption. It was concluded that there is still scope for improving production efficiency of smallholder coffee producers in Kenya. Furthermore, the results indicate that cost inefficiencies increase significantly with farm size but decrease with the level of farm-incomes and amounts of credit available to each household.

Most of the studies reviewed above used the stochastic frontier approach to study efficiency in crop agriculture. Apparently, there are relatively few studies which have used the stochastic frontier to study efficiency of livestock production (see Kumbhakar *et al.*, 1989). This study will attempt to bridge this gap by using this approach to study efficiency of smallholder dairy production in a LDC, Kenya. Firm-farm specific efficiency will be directly estimated from the dual stochastic frontier functions. After the liberalization of the dairy industry in 1992, smallholder dairy farmers can sale liquid milk through various outlets i.e. neighbouring households, milk traders (hawkers), local hotels/schools/kiosks and local milk cooperative societies. They access dairy inputs and services from liberalized markets. Therefore, it is perceived that there is adequate variability of input and output prices making it suitable for the use of the dual models to estimate farm specific efficiency.

2.3. Overview of Supply Response and Production Structure

The supply response analysis determines how producers would respond to changes in product and factor inputs, in technology and in access to certain constraining factors of production. This analysis is central to policy decisions in that it helps us understand the impact that alternative policy packages or external shocks may have on the producers themselves. Through the changes it induces in commodity supply and factor demand, the analysis of supply response and production structure, is an essential component of models that seek to explain market prices, wages and employment, external trade and government fiscal revenues (Sadoulet & de Janvry, 1995).

In the past policy documents, the emphasis in the governments agricultural and livestock policy is firmly focused on achieving growth in output (e.g. RoK, 1986; 1994). At the same time, concerns are growing about the extent to which these policy goals are sustainable within a liberalized market environment particularly in the rural areas where provision of public services (e.g. AI, animals health) were expected to be replaced by private entrepreneurs. In this economic scenario, Byerlee (1993) argues that realizing future productivity gains would require significant adjustments in the institutions serving agriculture. Changes in the policy systems would undoubtedly form part of these adjustments. Part of this study addresses some of the issues that need to be confronted in determining what adjustments might be appropriate for the marginal zones. In particular, this part of the study explores the production response, of a group of smallholder dairy farmers in the marginal zones of Machakos and Makueni Districts, to changes in prices and other factors related to technology and fixed inputs, using both cost and profit function approaches.

2.3.1. Conceptual Framework of Production Structure and Supply Response

There are two elements in determining a producer's response (Sadoulet & de Janvry, 1995). One is the technological relation that exists between any particular combination of inputs and the resulting levels of output; this is represented by the production function. The other is the producer's behaviour in choice of inputs, given the level of market prices for a commodity and factors that can be traded, and the availability of fixed factors whose quantity cannot be altered in the period of analysis. Integration of these two elements leads to the definition of the profit or the cost function, which gives the maximum profit or the minimum cost that a farmer can obtain given the environment, and to a direct method to determine the optimal decision on output supply and factor demand. This is the approach adopted for this analysis. It is fundamentally a systems approach, with prices and non-price factors treated symmetrically. However, neither uncertainty nor rigidity in implementation of the optimum decisions is considered in the analysis.

2.3.2. Prior Studies on Production Structure

Turkish livestock supply has struggled to keep pace with the current growth in domestic demand. The breed composition and feeding practices are two important factors which affect yield growth in Turkey. Fuller *et al.*, (1999) lounged a study on farm-level feed demand in Turkey with an objective to increase understanding of feed demand by providing estimates of the price responsiveness of feed demand on dairy, beef and other livestock. They also sought to determine whether feed input quality increases feed efficiency and animal productivity. The translog cost function with derived feed input demands was used for the analysis. A system of feed input demand share equations subject to cross equation restrictions was estimated using an iterative version of Zellner's seemingly unrelated regression (SUR) technique. The results showed that Turkish producers consider quality formula feeds to be an integral part of their feed regime. As feed prices change, producers substitute grains, oilseed meals, and by-product feeds for formula feeds; however, the demand for lower quality feeds tends to be more elastic than for formula feed. Estimation of unit feed inputs and yields in the dairy cattle sector revealed that increasing quality feeds significantly improves feed efficiency and increases productivity. Although there does not appear to be a difference in the impacts of quality feed on feed efficiency for different breeds of cattle, yields of domestic and crossbred cattle increase nearly twice as much as cultured cattle.

The policy implications of these results are that Turkey could improve its ability to meet future demand for livestock products by implementing government policies that increase the availability of formula feeds and quality feed ingredients. Opening domestic markets to lower-cost imported feed grains is one policy option that could lower the cost and increase the availability of quality feedstuffs. In addition, policies that encourage producers milking crossbred and domestic cattle to increase their use of quality feeds will yield a short-run increase in milk output, while the long run productivity of the herd can be raised by increasing the share of cultured cattle in the dairy herd.

The role of imports as an alternative input to domestically supplied capital and labour in the U.S. economy for the period 1970-1993 was examined by Yanikkaya (2004) using the aggregate translog cost function estimated simultaneously with the cost share equations for capital, labour and imports. The system of equations consisting of the cost function and two of the three cost-share equations is estimated as a simultaneous system (with import cost-share equation being dropped). The iterative Zellner's seemingly unrelated regression estimation procedure is applied to estimate the parameters of the system of equations, yielding estimates which are asymptotically equivalent to maximum likelihood estimates and invariant to the cost-share equation dropped. This method of analysis allows estimates of econometric measures of elasticities of substitution between inputs for each year, and the annual own and cross-price elasticities of demand for inputs. The results imply conventionally downward slopping demand curves for inputs but they are inelastic. The demand for labour is most inelastic, followed by imports and capital respectively. The results also show that inputs are gross substitutes; the partial elasticity of substitution between capital and imports is higher than the partial elasticity of substitution between labour and imports.

Kant and Nautityal (1997) studied the production structure of the Canadian logging industry using duality theory in production and costs. An unrestricted translog cost function and nine resticted cost functions are each estimated simultaneously with the cost share equations using the iterative Zellner method. The elasticities of substitution among pairs of inputs and price elasticities of factor demands are computed. The results show that the production structure is homogeneous, but it is not subject to the unitary elasticity of substitution. The Morishima elasticities indicate that the substitution of capital by labour or energy is easier than the substitution of labour or energy by capital. Substantial economies of scale are observed in the logging cost. It is concluded that with rising prices of capital, the Canadian logging industry would have a greater tendency to substitute capital by other inputs. The substitution of labour and capital by material will be possible only by using poorly trained labourers and less sophisticated machinery, respectively, and it will lead to a tendency to waste standing timber. Hence during periods of rising prices of other factors, specifically labour and capital, the forest managers, the Ministry of natural resources should use a more strict policy and should increase the intensity of monitoring of logging operations in agreement forests.

Huang (1991) analysed the demand for labour, capital and energy in the U.S. food manufacturing industry using Morishima elasticities of substitution. The food manufacturing industry faced a steady increase in the price ratio between labour and capital and a sharp increase in the price of fuel and energy during 1970s but a continued decrease since 1981. To make decisions in resource allocation, food manufacturers needed information on the nature of industrial demand for factor inputs. The system of input demand cost share equations for labour, capital and energy is estimated using Zellner's seemingly unrelated regression method with one of the input share equations deleted from the system. The results show that the demand for capital services is more highly elastic than for labour and energy. Thus, any policy measures to reduce the price of capital services, such as investment tax credits and lower interest rates, would significantly increase the demand for capital. The demand elasticities of labour, capital, and energy in response to energy price changes are relatively low. They indicate that the relatively large changes in the prices of fuel and energy experienced over the sample period did not cause much adjustment in factor utilization. The Morishima elasticitities indicate that laour, capital, and energy are substitutes especially between labour and capital. This is evidenced by the trends in the food manufacturing industry to substitute computers and automated machines for human operations in light of the steady increase in the labour to capital price ratio

Mergos and Youtopoulos (1987) examined Grecian feed-input demand, its composition and substitutability with other aggregate inputs in the context of long term and structural changes that take place in the livestock sector in the course of economic development. The translog cost function was formulated but only the associated input demand shares were estimated. The results indicate that the livestock sector of Greece in the period 1960-1981 was moving towards a capital and feed intensive technology and away from a labour and land grazing intensive technology. Grain was the main feed component and it seemed like it would remain so in the future. Grain has strong substitution and complementary relations with the rest of the feed components. The observed increase in grain use intensity in the sector was associated with changing capital/labour price ratios, declining price of grain relative to other feed components and the development of the compound feed industry.

Several other studies have used the translog cost function and input share demand system to study production structure (e.g. Nautiyal and Singh, 1985; Lopez, 1980), import demand (e.g. Truett *et al.*, 1994), economies of scale (Larue *et al.*, 1996; Christensen and Greene, 1976), factor substitution and technical change (Kako, 1978; Ray, 1982) etc. in various sectors of economy. These studies contribute to the current study by exposing the versatility afforded by the translog formulation which permits measurement of different impacts that exogenous variables have within and across input demand and the cost function. This approach would be applied in the current study to determine the structure of dairy production in the marginal zones. Policy related elasticity estimates with respect to variable dairy inputs (e.g. protein feeds, animal treatment, labour etc.) and fixed inputs which are usually considered constraints to dairy production in the marginal zones would be estimated.

2.3.3. Prior Studies on Supply Response Analysis

Sidhu and Baanante (1981) undertook a study on the supply response of wheat in Indian Punjab. The data used for the study was Farm-level data for Mexican Wheat Varieties (MWV) from the Indian Punjab. They applied the normalized, restricted, translog profit function and the corresponding system of derived demand as the method of analysis in order to generate policy-related empirical estimates for wheat supply and input demand functions. The flexibility afforded by translog formulation permitted measurement of the different impacts that exogenous variables have within and across input demand and output supply functions. Policy relevant elasticity estimates with respect to variable inputs and output prices, fixed inputs, a few soil-related 'state-of-nature variables measured by soil analysis, and education, which are usually considered constraints to farm production, were obtained, and two examples of policy applications were developed.

The results showed that the impact of the exogeneous variables varies across input demand equations, quite consistent with *a priori* theoretical expectations. All fixed inputs were important in influencing wheat supply. Expansion in farm capital, in the form of implements and machinery, for example, decreases significantly the demand for animal power, contributes positively to wheat supply, but is not significant for labour and fertilizer demands. Expansion of irrigation increases demand only for farm labour and fertilizer but not for animal power. Expansion of education increases demand for all variable inputs but, more importantly for fertilizer and animal power. It also influences wheat supply significantly. An exogenous increase in land quantities also increases wheat supply and demand for all variable inputs of production. Of the three soil characteristics (soil PH, soil organic carbon, and soil potassium and Phosphorous) included in the analysis, the soil PH appeared to be the most important environmental variable. It had a strong negative influence on wheat supply.

Pakistan had a stated policy to increase basmati rice production through price support measures and liberalization of input markets. For example, in the 1993-1998 plan period, a 6.8. percent annual output growth target was earmarked for the rice sub-sector.

Farooq *et al.* (2001) undertook a study to assess the scope for price support policy to achieve growth targets and whether additional assistance was needed from non-price policy measures. The method of analysis adopted was the translog profit function. A systems approach was applied to estimate the input demand, output supply and the profit function equations. The study used farm household survey data from the Punjab, Pakistan for 1995-1996.

The empirical results yielded broadly satisfactory results both in terms of economic theory and statistical fit. The own price elasticity for paddy supply response (an elasticity of 0.27) implied that a substantial increase in support prices would be required to obtain a small expansion in their supply. Specifically, in order to achieve the 6.8 per cent annual growth target, the government would be required to increase its support prices by about 26 percent per annum. This study was done at a time of price controls by the governments in developing countries. The current study is being done after market liberalization in these countries and it is possible that farmers have quite elastic responses to market prices.

Fertilizer use is found to be particularly important in the decisions on resource allocation in paddy production. Compared with the other variable inputs, the elasticity of demand for fertilizer price was the highest, and the own-price elasticity of demand for fertilizer was also relatively large. This suggested that due consideration to the price of fertilizer is merited when deciding upon the support prices of basmati paddy.

Of the fixed inputs, the area under paddy and the age of basmati varieties were found to be important factors contributing to the supply of paddy. Paddy area also influenced significantly the demand for all variable inputs. Given the inelastic supply response to the rice price, the importance of allocating a proportionately larger area to relatively better yielding varieties is all the more evident. It was concluded that in order to increase aggregated production of basmati paddy in the study area, a support price policy appears to be inadequate. Supplementary measures aimed at promoting expansion in area under basmati paddy and improving its varietal age on farmers' fields, possibly through extension projects, are also desirable. It was further suggested that while deciding the support price for paddy, fertilizer prices needed careful considerations.

Subramaniyan and Nirmala (1991) used the translog profit function to study the supply response of cotton in nine states of India. The profit function and the derived demand input share equations were estimated as a system. The cotton supply and input demand elasticities were estimated. The results show that the translog profit function is statistically more appropriate than the frequently used, but more restrictive Cobb-Douglas model. The supply of cotton emerged highly elastic with respect to fixed inputs of land and capital. The demand for labour and fertilizer showed high elasticity with respect to land, indicating that a one per cent increase in land is likely to bring about a more than one percent increase in demand for labour and fertilizer. The cross-price elasticities of variable inputs with respect to capital revealed negative impact, implying that the variable inputs are complement to capital.

These studies contribute to the current study by exposing the versatility afforded by the translog formulation which permits measurement of different impacts that exogenous variables have within and across input demand and output supply functions. This approach would be applied in the current study to determine the structure and the supply response of dairy production in the marginal zones. Policy related elasticity estimates with respect to variable dairy inputs (e.g. protein feeds, roughage feeds, own produced feeds, labour), milk prices and fixed inputs which are usually considered constraints to dairy production in the marginal zones would be estimated.

2.4. Conclusion and Justification of the Study

In the past, numerous studies have examined dairy technology adoption and its impact on smallholders in Kenya. Others have addressed the effect of liberalization policy on dairy industry development. Few past studies have measured economic efficiency using the traditional production function which may not be appropriate when farmers face different prices and have different factor endowments. Others used the profit function to determine relative efficiency between groups of producers. However, the average profit function approach does not provide a numerical measure of farm specific efficiency. Most studies have focused on Kenya's highland areas because dairy cattle ownership is more prevalent among smallholders in this zone. In general, these studies relied on tabular comparisons of key variables for households owning dairy cattle and/or those without them, whereas the marketing studies relied on descriptive analysis of formal and informal markets of dairy products. Although few of them used the production function and the profit function approach, none of them applied the more recent methodologies in measuring economic efficiency and production response that provide better empirical estimates of levels of farm specific efficiency, production structure and supply response. Further, while these studies were useful in understanding the impacts of policy and technological change, there is now need to study and determine the efficiency of dairy production and production response and develop policy recommendations which can enhance dairy expansion in the marginal zones.

The marginal zones of Kenya are of interest because of limited dairy development, relatively higher temperatures, seasonal rains and greater disease challenges in contrast with conditions in the temperate highlands. Moreover, economic development in the marginal districts has lagged behind other regions of Kenya. Household incomes are low and unemployment is high because there are no cash crops like in high potential zones or off-farm employment activities like tourism and fishery industry in the coastal areas of Kenya. There is therefore a continuing need for technologies that increase returns to agricultural production in this zone. Also, areas with similar climatic and dairy demand characteristics exist in Sub-Saharan Africa. So, an understanding of the performance of the smallholder dairy production in the marginal zones of Kenya can provide insights about existing opportunities in much of marginal zones in Sub-Saharan Africa.

2.5. Contribution and Limitations of the Study

In the last two decades, smallholder exotic dairy production has been established in the marginal zones; an area considered unable to meet the requirements of the high performing exotic breeds in 1960s and 1970s. However, little is known about the performance of the smallholder dairy in this zone, deemed to be hostile to exotic dairy breeds. A number of studies have been carried out on: dairy technology adoption in the high potential, coastal and Western region, the effect of liberalization policy on dairy industry and economic efficiency using the traditional production function in the high potential zones of Kenya. However, there is no documented literature following up the establishment of smallholder dairy in the marginal zones, besides the government's district livestock annual reports.The current study therefore aims at making a contribution to the empirical knowledge of the economic performance of the smallholder exotic dairy, the emerging associated production structure and supply response in the marginal zones.

The limitations of this study relate to the methodologies adopted and the data used. For example, the stochastic frontier approach assumes that all inputs have been taken into consideration. However, in this study as well as others, it is possible to raise questions about whether all inputs have actually been accounted for since farms that are apparently inefficient may just use less of certain unmeasured inputs. Another main limitation is the fact that dairy is relatively a new enterprise in the marginal zones. So, farmers might use more of one input in a category and fail to use the others. For example, farmers may be using mineral salts but fail to use concentrates. This results in many missing cases, making it impossible to use the individual inputs as variables. The profit function can face limitations especially where farm households realize zero or negative profits at the prevailing market prices. This situation is expected to be prevalent in the marginal zones where market oriented dairying is relatively a new farm business activity. It may result in reducing the number of observations and ultimately, it lowers the degrees of freedom in the analysis. The expected replacement of public service provision by private entrepreneurs after liberalization has partially occurred in some of the areas like the marginal zones. It is important to note that this may cause a limitation of analysing the production structure particularly where the farmers might not have access to these services. Finally, the systems analysis using LIMDEP (Green, 2002) can only allow eleven variable cases. This is because the associated quadratic and cross terms would eventually make the model too large to accommodate more than eleven cases. This limits the number of institutional and the socio-economic variables which can be included in the system for analysis.

CHAPTER III

THEORETICAL BACKGROUND AND RESEARCH METHODOLOGY

3.1. Introduction

This chapter develops the theoretical foundations of the analytical models applied in this study based on production economic theory. To achieve the objectives of the study, three interrelated approaches to production analysis are employed. The first analytical model is based on the stochastic cost frontier which will be used to determine the attributes that influence cost inefficiencies. An effort will be made to determine the preferred functional form among the translog, Cobb-Douglas and quadratic stochastic cost frontier functions. In the second analytical model, the dairy production structure is analysed using the cost function approach and input demand analysis in the marginal zones. The systems approach framework which permits measurement of different impacts that exogenous variables have within and across dairy input demands will be adopted. In the third analytical model, the output supply is analysed using the profit function approach to supply and input demand analysis in the marginal zones. The theoretical duality relationships inherent in the profit function, input demands and output supply are extensively utilized in this analysis. They are estimated simultaneously as a system.

Several assumptions underlie the theoretical framework of this study. The first assumption is that there is variability of both input and output prices in dairy production. The dairy industry in Kenya was liberalized in 1992 when the policy of price decontrol of the milk markets was implemented (RoK, 1993). The provision of animal health and breeding services was fully decontrolled in 1994 (Omiti, 2002). As a result, smallholder dairy farmers in the marginal zones make individual choices on the milk marketing outlets.

They sell liquid milk to the neighbouring households, local kiosks/schools/hotels, private milk traders (hawkers) or milk cooperative societies where the farmers have membership. In the input markets, farmers get AI and animal health services from private practitioners or from the cooperative societies or both. The competitive environment for the dairy output and input markets is expected to ensure a major variability in input and output prices. Consequently, the use of the dual models in estimating efficiency is expected to result in superior results. The second assumption is that smallholder dairy farmers maximize profits i.e. they started market oriented dairying as a farm business with an objective of earning profits. The study also assumes that all the production input prices and socio-economic characteristics are included in the specification of the stochastic frontier model. Finally, the composed error term is $\varepsilon_i = v_i + u_i$ where v_is are assumed to be independently and identically distributed $N(0,\sigma_v^2)$ two sided random errors, independent of the inefficiency error, u_is. Additionally, u_is are assumed to be non-negative truncated half-normal distribution, $N(0, \sigma_u^2)$.

Following this introduction, Sections 3.2, 3.3 and 3.4 elaborate the descriptive and econometric models applied in this study. The analytical models developed analyse the three main issues central to this study. These models have considerable interdependence and complementarily. The description of each analytical method is preceded by a review of its theoretical foundations and empirical applications. The methodological hypotheses used in each model are laid down. Then section 3.5 describes the source from which data will be drawn, the way it will be collected and how the variables will be developed.

3.2. Theoretical Basis of the Stochastic Frontier Cost Function

Farm efficiency and the question of how to measure it is an important subject in developing countries' agriculture. There are three distinct approaches to measurement based on cost, profit, and production functions (Parikh *et al.*, 1995). Farrell (1957) distinguishes between technical and allocative efficiency (or price efficiency) as a measure of production efficiency through the use of a frontier production and cost function respectively. The production technology can be represented inform of cost function. The cost function represents the dual approach in that technology is seen as a constant towards the optimizing behaviour of firms (Chambers, 1983). In the context of cost function any error of optimization is taken to translate into higher cost for the producers. However, the stochastic nature of the production frontier would still imply that the theoretical minimum cost frontier would also be stochastic.

The cost function can be used to simultaneously predict both technical and allocative efficiency of a firm (Coelli, 1995). Also, it can be used to resurrect all the economically relevant information about farm level technology as it is generally positive, non-decreasing, concave, continuous and homogeneous to degree one in input prices (Chambers, 1983). Chambers, (1983) gives detailed proof of the properties of a cost function. This section has adopted a stochastic cost frontier based on the Battese and Coelli (1995) model. The model allows inefficiency effects to be a function of a set of explanatory variables, the parameters of which are estimated simultaneously with the stochastic frontier. The approach is stochastic and the observations may be off the frontier because they are inefficient or because of random shocks or measurement errors. The cost function approach is preferred over the profit function approach to avoid problems of estimation that may arise in situations where farm households realize zero or negative profits at the prevailing market prices. This situation is expected to be prevalent in the marginal zones where market oriented dairying is relatively a new enterprise and the farmers are still learning the art of cost minimization to produce a given level of milk output.

The stochastic cost function is defined as:

$$C_i = f(y_i, w_i) + (v_i + u_i) \qquad (3.1)$$

where v_is values are assumed to be independently and identically distributed $N(0,\sigma^2_v)$ two sided random errors, independent of the u_is. u_is are non-negative unobservable random variables associated with cost inefficiency, which are assumed to be identically and independently distributed as truncations at zero of the \N(0 , σ^2_u)\ distribution, μ_i being a vector of effects specific to smallholder dairy farms in the marginal areas.

In the cost inefficiency effects model, the error term is composed of the following two components: cost inefficiency effects and statistical noise. The two error components represent two entirely different sources of random variation in cost levels that cannot be explained by output and input prices. The cost inefficiency effects could be specified as:

$$u_i = \delta z_i + W_i \qquad (3.2)$$

where z_i is a vector representing possible efficiency determinants, and δ is a vector of parameters to be estimated. W_i, the random variable, is defined by the truncation of the normal distribution with mean zero and variance σ^2. The parameters of the stochastic frontier and the inefficiency model are simultaneously estimated. u_i provides information on the level of cost inefficiency of farm i. The level of cost inefficiency CI_i may be calculated as the ratio of frontier minimum cost (on the cost frontier) to observed cost. This measure has a minimum value of one. An estimated measure of cost efficiency for dairy farm i is:

$\text{CI}_i = \exp(-u_i)$ (3.3)

The unobservable quantity may be obtained from its conditional expectation given the observable value of e_i (where $e_i = v_i + u_i$).

3.2.1. Econometric Specification of the Empirical Model

The translog cost function which is a second-order approximation of the output, input prices and fixed factors is applied in the current study. The translog cost function is chosen due to its flexibility and its variability in elasticity (Chambers, 1983; Sadoulet & Janvry, 1995). The advantage of the translog cost function is that it contains fewer parameters than some other flexible functional forms. The stochastic frontier translog cost function is defined as:

$$\ln C_i = \alpha + \alpha_q \ln Q_i + \sum_i^n \alpha_i \ln P_i + \frac{1}{2}\beta_{qq}(\ln Q_i)^2 + \frac{1}{2}\sum_i^n \beta_i \ln P_i \ln P_i + \sum_i^n \beta_{ij} \ln P_i \ln P_j$$

$$+\sum_{i=1}^n \beta_{qi} \ln Q_i \ln P_i + \gamma_m \ln Z_m + \frac{1}{2}\gamma_{mm}(\ln Z_m)^2 + \sum_{m,i}^n \gamma_{mi} \ln Z_m \ln P_i + \sum_{m,q}^n \gamma_{mq} \ln Z_m \ln Q_i + e_i$$

(3.4)

The symmetry assumption holds i.e. $c_{ij} = c_{ji}$ and $h_{mi} = h_{im}$.

The inefficiency model (u_i) is defined as:

$$u_i = \delta_0 + \sum_{d=1}^n \delta_d W_d + \omega \quad (3.5)$$

where: C_i represents total production cost, Q_i represents annual output of milk (litres), P_i is a vector of variable input prices, Z_m is the vector of fixed inputs and e_i is the disturbance term. W_d is a vector of variables explaining inefficiency in the model.

Following Aigner *et al.* (1977) and Meensen & Van de Broeck (1977), the disturbance term (e_i) is assumed to be a two-sided term representing the random effects in any empirical system. The error term, e_i is taken to behave in a manner consistent with the stochastic frontier:

$$e_i = v_i + u_i \tag{3.6}$$

The systematic component v_i accounts for random disturbance in costs due to factors outside the farmer's control, such as animal disease outbreaks, flood and weather. It is assumed to be independently and identically distributed as N(0, σ_v^2). u_i is one-sided disturbance term used to represent cost inefficiency. Thus, $u_i = 0$ for a farm whose costs lie on the frontier, $u_i > 0$ reflects cost inefficiency relative to the stochastic frontier and represents a farm whose cost is above the frontier. u_i is assumed to be identically and independently distributed as N(0, σ_u^2) i.e. the distribution of u_i is half-normal. The population average efficiency is given by:

$$E(e^{-u}) = 2e^{\frac{1}{2}\sigma_u^2}\left[1 - \phi(\sigma_u)\right] \tag{3.7}$$

Where, ϕ is the standard normal distribution function. Measurement of farm level specific inefficiency, e^{-u}, requires first the estimation of the non-negative error u_i i.e. decomposition of e_i into its two individual components, u_i and v_i. Following Jondrow *et al.* (1982), the farm-specific estimates of inefficiency, u_i for each inefficiency are derived from the conditional distribution of u given ($e_i = v_i + u_i$). Given the normal distribution of v and half-normal distribution of u, the expected value of farm-specific inefficiency u_i, given $e_i = v_i + u_i$ is:

$$E(e^{-u} / e_i) = \frac{\sigma_u \sigma_v}{\sigma}\left[\frac{\phi(\varepsilon_i \lambda / \sigma)}{1 - G(\varepsilon\lambda / \sigma)} - \frac{\varepsilon_i \lambda}{\sigma}\right] \tag{3.8}$$

Where, σ_v^2 and σ_u^2 are the variance of v_i and u_i, $\lambda = \sigma_u / \sigma_v$, $\sigma^2 = \sigma^2_v + \sigma^2_u$ and ϕ and Φ are the standard normal density (PDF) and the cumulative distribution function (CDF), respectively.

3.2.2. Estimation Procedure

The stochastic frontier models are the most commonly used to study production efficiency. In a number of previous studies, a two-stage procedure to estimate efficiency was employed (Ali and Flin, 1989; Bedassa and Krishnamoorthy, 1997; Karanja, 2002; Parikh *et al.*, 1995). In the first-step, the inefficiency terms in the stochastic model, u_i are predicted and the corresponding inefficiencies estimated. In the second-stage, the predicted efficiency indices are regressed against institutional and socioeconomic factors hypothesised as being responsible for the estimated farm-specific inefficiencies. Although this approach has been recognized as a useful one, the two-stage estimation procedure utilized has also been recognized as one which is inconsistent in its assumptions regarding the independence of the inefficiency effects in the two estimation stages (Coelli, 1996).

Battese and Coelli (1995) extended the stochastic production frontier model by suggesting that the inefficiency effects can be expressed as a linear function of the explanatory variables, reflecting farm-specific characteristics. The advantage of Battese and Coelli (1995) model is that it allows estimation of the farm-specific efficiency scores and the factors explaining efficiency differentials among farmers in a single stage estimation procedure. This analysis utilizes Battese and Coelli (1995) model by postulating a cost function, which is assumed to behave in a manner consistent with the stochastic frontier concept. The stochastic frontier cost models, equation 3.4 with the behavioural inefficiency model, equation 3.5 are estimated in one step Maximum Likelihood Estimation (MLE) using LIMDEP programme (Greene, 2002). The results of this analysis are discussed in Chapter 4.

3.2.3. Hypotheses Testing

Tests of hypothesis of interest are obtained using the generalized likelihood-ratio statistic defined by:

$$LR=-2\{\ln[L(H_0)/L(H_1)]\} \qquad (3.9)$$

where $L(H_0)$ and $L(H_1)$ are the values of the likelihood function under the null and alternative hypotheses, H_0 and H_1 respectively. The generalized likelihood-ratio statistic is assumed to have asymptotic chi-square distribution (mixed chi-square) if the appropriate null hypothesis, H_0 is true. To perform these tests the stochastic frontier function under the null, H_0, is estimated by imposing the appropriate restrictions before estimating the model. The following hypothesis will be tested:

Hypothesis 1: H_0: $\beta_{qq} = \beta_{ii} = \beta_{ij} = \beta_{qi} = \gamma_{mm} = \gamma_{mi} = \gamma_{mq} = 0$

This null hypothesis identifies an appropriate functional form between the restrictive Cobb-Douglas and the translog cost function. It determines whether smallholder farms experience constant returns to scale. The hypothesis specifies that the cross terms in 3.4 are equivalent to zero, ultimately collapsing the translog specification to a Cobb-Douglas profit function. The results of this analysis are discussed in Chapter 4.

Hypothesis 2 : H_0: $\lambda = \delta_0 = \delta_1 = \delta_2 =,\ldots,= \delta_p$

This null hypothesis specifies that the cost inefficiency effects are not present in the model at every level. Thus the inefficiency effects are not a linear function of the socioeconomic and institutional attributes specified. Hence the joint effect of these attributes on cost inefficiency is statistically insignificant.

Hypothesis 3: H_0: $u = 0$

This null hypothesis specifies that each farm is operating on the cost efficient frontier and that the asymmetric and random cost efficiency in the inefficiency effects is zero. In other words, the inefficiency effects are absent from the model. Hence the inefficiency effects are not stochastic, ultimately collapsing the stochastic frontier cost function estimated using MLE in equation 3.4 to an average cost function estimated using OLS. The alternative hypothesis is the presence of inefficiency effects in the model.

Hypothesis 4: H_0: $\delta_0 = \delta_1 = \delta_2 =,...,= \delta_p = 0$

The fourth null hypothesis considered specifies that the inefficiency effects are not a linear function of the socioeconomic and institutional variables specified in the inefficiency model. It tests the joint effects of all the inefficiency explanatory variables on the inefficiency of production in the model.

3.3. Dairy Production Structure: Theoretical Framework

The second area of analysis in this study determines the production structure of dairy in the marginal zones. An industry's production structure can be studied empirically using either a production function or a cost function. However, the choice should be made on statistical grounds (Kant and Nautiyal, 1997). Direct estimation of the production function is more convincing in the case of endogenously determined output levels, while in the case of exogenously output levels, the cost function estimation is preferable (Christensen and Green, 1976). In most cases, the dairy sector competes with other enterprises for factors of production, and this leads factor prices to be exogenous. Since the arguments of the cost function are the output and the factor prices, its estimation is statistically more logical than that of the production function. On the other hand, duality theory allows for the recovery of all information regarding the production structure from the cost function. Because of very specific features, i.e. no *a priori* restrictions on the substitution possibilities and variation of scale economies with the level of output (which is essential to enable the unit cost curve to attain the classical U-shape), the translog cost function (Christensen *et al.*, 1971, 1973) has been chosen for this analysis.

3.3.1. Specification of the Empirical Model

A general form of the translog cost function for the seven inputs (protein feeds, roughage feeds, animal treatment, tick administration, labour, own produced feeds and grazing area can be expressed as:

$$\ln C_i = \alpha + \alpha_q \ln Q_i + \sum_i^n \alpha_i \ln P_i + \frac{1}{2}\beta_{qq}(\ln Q_i)^2 + \frac{1}{2}\sum_i^n \beta_{ii} \ln P_i \ln P_i + \sum_i^n \beta_{ij} \ln P_i \ln P_j$$

$$+ \sum_{i=1}^n \beta_{qi} \ln Q_i \ln P_i + \gamma_m \ln Z_m + \frac{1}{2}\gamma_{mm}(\ln Z_m)^2 + \sum_{m,i}^n \gamma_{mi} \ln Z_m \ln P_i + \sum_{m,q}^n \gamma_{mq} \ln Z_m \ln Q_i$$

(3.10)

where $\beta_{ij} = \beta_{ji}$ for all i, j and the function is homogeneous of degree one in prices of all variable inputs and output. The definition of the variables and the notation used are as follows:

C_i = Total variable cost of production normalized by the labour wage (w_i);

P'_i =Price of the ith input (P_i) normalized by the labour wage (w_i);

i = 1, protein feeds; 2, roughage feeds; 3, animal treatment; 4, tick administration;

5, own produced feeds; Z_m = grazing area, $\alpha's, \beta's$ and $\gamma's$ are the parameters to be estimated. To correspond to a well-behaved production function, a cost function must be homogeneous of degree one in the input prices, which requires the following conditions to be satisfied:

$$\sum_i \alpha_i = 1 \tag{3.11}$$

$$\sum_i \beta_{qi} = 0 \tag{3.12}$$

$$\sum_i \beta_{ij} = \sum_j \beta_{ij} = \sum_i \sum_j \beta_{ij} = 0 \tag{3.13}$$

The restriction of linear homogeneity in the input prices is imposed by normalizing cost and the other prices by the labour wage rate (Green, 2002). The translog cost function can be estimated directly or in its first derivatives which, by Shepard's Lemma gives the factor shares. Thus, logarithmically differentiating equation 3.10 with respect to input prices yields:

$$\frac{\partial \ln C}{\partial \ln P_i} = \frac{P_i X_i}{C_i} = S_i \tag{3.14}$$

where S_i indicates the cost share of the ith input factor. The translog cost function thus yields the cost share equations:

$$S_i = \alpha_i + \beta_{qi} \ln Q + \sum_i \beta_{ij} \ln P_j + \gamma_{ij} \ln Z_m \tag{3.15}$$

and i=1 for protein feed share, 2 for roughage feed share, 3 for tick control share, 4 for treatment administration share, 5 for labour input share and 6 for own produced feed share. Both sets of estimation equations are linear in logarithms and have proper exogenous variables on the right hand side if the analysis pertains to firm-farms or an industry (Binswanger, 1974). The necessary cross equation constraints are imposed in the translog cost function and the input demand system. Within the factor demands, symmetry of the input demand equations (i.e. $\beta_{ij} = \beta_{ji}$) is imposed. It is generally observed that very large gains in efficiency often follow when the cross equation restrictions are imposed (Green, 2002). The β_{ij} parameters have little economic meaning of their own. However, they are related to the variable elasticities of substitution and of factor demands (Binswanger, 1974).

3.3.2. Estimation Procedure

It is possible to estimate the parameters of the cost function using ordinary least squares (OLS), but that neglects the information contained in the cost share equations. An alternative estimation procedure is to estimate the cost shares as a multivariate regression system (Berndt and Wood, 1975). However, in this approach, the parameters associated with output and output cross terms which are found only in the cost function cannot be estimated. The optimal procedure is to jointly estimate the cost function simultaneously with the cost share equations as a multivariate regression system. Inclusion of the cost share equations in the estimation results in more degrees of freedom without adding any unrestricted regression coefficients, and results in more efficient parameter estimates.

Additive disturbances are assumed for the cost function as well as for each of the share equations. Following Zellner (1962), it is also assumed that the error in each equation is homoscedastic but that there is a nonzero correlation between contemporaneous disturbance terms across equations. In view of the adding up requirement of the input shares, one equation, labour input demand share, is excluded from the system. By deleting one of the share equations from the system and using the iterative Zellner estimation procedure until convergence, maximum-likelihood estimates are realized. The iterative Zellner procedure is a computationally efficient method for obtaining maximum-likelihood estimates and has been used by researchers for estimating translog cost function (Christensen and Greene, 1976; Meil and Nautiyal, 1988; Kant and Nautiyal, 1997). We also use the iterative Zellner method. The systems analysis is implemented by use of the LIMDEP software (Greene 2002). The hypotheses of joint estimation of the cost function and the system of input share demands can be tested by the likelihood ratio test. The likelihood ratio (see equation 3.8) is equal to double the difference between the logarithmic values of likelihood functions of the unrestricted and the restricted models. This ratio has a χ^2 (Chi-square) distribution with degrees of freedom equal to the number of independent restrictions imposed.

3.2.3. Hypothesis Testing

Generalized log likelihood ratio test will be used to test several hypotheses related to the system of dairy production structure in the marginal zones. The hypotheses attempt to establish whether the translog cost function is a simultaneous system with the input demands in the production structure. The test hypotheses are of the cross equation parameter restrictions in the share equations by estimating them as a system without the cost equation, and with and without the cross equation equality restrictions. They are joint hypotheses on the validity of the symmetry and parametric constraints across the cost and input demand equations. A Chi-square test statistic with good asymptotic properties is conducted to test this hypothesis. The first hypothesis is that estimation of input demand system with cross equation equality restrictions is not different from the simultaneous estimation of the translog cost function/input demand system. The second hypothesis is that estimation of input demand system without cross equation equality restrictions is not different from the simultaneous estimation of the translog cost function/input demand system. And the third hypothesis to be tested is that the estimation of input demand system with and without cross equation equality symmetry restrictions is not different. These tests attempt to establish whether dairy technology and input demands are integrated as a system.

3.2.4. Estimation of Input Demand and Substitution Elasticities

The parameter estimates of equation 3.4 are used to estimate the elasticities related to variable input demands, and the cost function. These elasticity estimates represent the structure of the production system for the dairy farms in the marginal areas. They are policy variables which indicate different impacts that exogenous price variables have within and across input demands. They are evaluated at averages of the S_i and are linear transformations of the β_{ij} parameter estimates of the cost function and input demand shares.

Fuller *et al.* (1999) has shown that the price elasticities of demand for the inputs can be calculated as:

$$\eta_{ii} = \frac{\beta_{ij}}{S_i} + S_i - 1 \quad (3.16)$$

$$\eta_{ij} = \frac{\beta_{ij}}{S_j} - S_j \quad (3.17)$$

where η_{ii} and η_{ij} are own and cross price elasticities respectively. The price elasticities of input demands for dairy production will be computed using the given derivations. Previously, Allen-Uzawa elasticity of substitution was used extensively to measure elasticity of substitution between input factors (Binswanger, 1974; Ray, 1982; Fuller et al., 1999; Kant and Nautiyal, 1997; Yanikkaya, 2004). However, it has been argued that it does not explain factor substitution explicitly (Blackorby and Russell, 1989; Christev and

Featherstone, 2005). Since it does not provide information about the comparative statics of factor shares, it cannot be interpreted as the marginal rate of substitution. An alternative measure of factor substitution is the Morishima elasticity of substitution. Blackorby and Russell (1989) argues that the Morishima (1967) elasticity of substitution is an exact measure of curvature or ease of substitution and that it provides complete comparative static information about relative factor shares. It preserves the salient features of Hicksian concept in the multifactor context. It is therefore a sufficient statistic for assessing the effects of changes in price or quantity ratios on relative factor shares. In addition, MES is a logarithmic derivative of a quantity ratio with respect to a marginal rate of substitution or a price ratio. According to Blackorby and Russell (1989), the MES can be calculated as $M_{ij} = \varepsilon_{ij} - \varepsilon_{ii}$. In this analysis, the Morishima elasticities will be computed to assess input substitution in dairy production.

3.3.5 Scale Economies in Dairy Production

Economies of scale are usually defined in terms of the relative increase in output resulting from a proportional increase in all inputs (Christensen and Green, 1976). However, it is more appropriate to represent scale economies by the relationship between total cost and output along the expansion path-where input prices are constant and costs are minimized at every level of output. A natural way to express the extent of scale economies is as the proportional increase in cost resulting from a small proportional increase in the level of output, or the elasticity of total cost with respect to output. We will define scale economies (SCE) as unity minus this elasticity:

$$\text{SCE} = 1 - \partial \ln C / \partial \ln Y \qquad (3.18)$$

This results in positive numbers for positive scale economies and negative numbers for scale diseconomies. Another indicator of scale economies is to measure it by the relation between total variable cost and output along the expansion path (Yanikkaya, 2004). Hence, the elasticity of scale (ε) is measured by the reciprocal of the elasticity of cost with respect to output. Using equation 3.18, the elasticity of scale can be computed as:

$$\varepsilon = (\partial \ln C / \partial \ln Y)^{-1} = \frac{1}{\alpha_q} \qquad (3.19)$$

where α_q is elasticity of cost with respect to output. Furthermore, SCE has a natural interpretation in percentage terms. Thus, elasticity of scale is the percentage change in total variable cost resulting from a 1 percent change in output. It is the responsiveness of total variable cost to a 1 percent change in output. In this study, scale elasticity for dairy production will be computed. The results of this section are discussed in Chapter 5.

3.4. Supply Response of Smallholder Dairy Farms: Theoretical Framework

The emphasis in the Kenya's government policy for dairy is firmly focused on achieving growth in output (RoK, 1986, 1994). At the same time, concerns are growing about the extent to which these policy goals are sustainable in a liberalized market environment. Byerlee *et al.*, (1993) and Ali (1995) suggest that realizing future productivity gains after structural adjustments in developing countries will require significant adjustments in the institutions serving agriculture. The supply response analysis addresses some of the issues that need to be confronted in determining what adjustments might be appropriate for dairy in the marginal zones.

The analysis of production structure using cost function approach is limited to the determination of different impacts that exogenous price variables have within and across input demands. It does not take into account the impacts of the price factors on output supply and profit which are of much interest in policy decisions. Neither does it account for impacts of institutional nor socio-economic setups on production structure which are of much concern to policy makers. Therefore, this section will explore the response of dairy farmers to changes not only of price factors, but also of institutional and socio-economic setups related to technology and fixed inputs, using profit function approach.

Specifically, the dairy households would be assumed to maximize 'restricted' profits, defined as the gross value of output less variable costs, subject to a given technology and given quantities of fixed factors. The resultant profit function depicts the maximum profit attainable for given input and output prices, the availability of fixed factors and the production technology. As we are dealing with a single output, liquid milk production, it is convenient to specify a normalized profit function, and fixed factors.

The profit function has two interesting properties: its derivative with respect to the price of a product is equal to the supply function of that product; and, its derivative with respect to the price of an input is equal to the negative of the demand function of that input (Sadoulet & de Janvry, 1995). These relations, called the Shephard's duality Lemma, are derived by differentiating the profit function and taking advantage of the first order conditions of the maximization problem. By solving the maximization problem, the behavioural equations of output supply and factor demands are obtained. It is desirable to estimate the input demand and output supply equations simultaneously. Such estimation is facilitated by the profit function approach which permits joint estimation of the profit and factor demand equations and ensures consistent parameter estimates (Yotopoulos & Lau, 1979; Sidhu & Baanante, 1981; Subramaniyan & Nirmla, 1991; Farooq *et al.*, 2001). This framework will be adopted for this study.

3.4.1. Specification of the Empirical Model

A generalization of the normalized restricted translog profit function for a single output e.g. liquid milk production is given by Farooq *et al.* (2001) and Sidhu & Baanante (1981):

$$\ln\pi^{'} = \alpha_0 + \sum_{j=1}^{5}\alpha_i \ln P^{'}_i + \frac{1}{2}\sum_{j=1}^{5}\sum_{k=1}^{5}\gamma_{ij}\ln P^{'}_i \ln P^{'}_j + \sum_{j=1}^{5}\sum_{l=1}^{6}\delta_{ik} lnP^{'}_i \ln Z_k + \sum_{l=1}^{6}\beta_k \ln Z_k$$

$$+\frac{1}{2}\sum_{l=1}^{6}\sum_{t=1}^{6}\theta_{lt}\ln Z_k \ln Z_h + \varepsilon \qquad (3.20)$$

where $\gamma_{ij} = \gamma_{ji}$ for all i, j and the function is homogeneous of degree one in prices of all variable inputs and output. The definition of the variables and the notation used are as follows:

$\pi^{'}$ = Restricted profit normalized by the price of output (P_y);

$P^{'}_i$ =Price of the jth input (P_i) normalized by the output price (P_y);

i = 1, Protein feeds; 2, Roughage feeds; 3, Animal treatment; 4, Tick administration; 5, wage rate; Z_k = quantity of fixed input k :- k =1, grazing area; 2, years of education; 3, extension visits; 4, walking ratio to tarmac road; 5, number of cows; and 6, distance to water point:

$\alpha_0, \alpha_i, \gamma_{ij}, \delta_{ik}, \beta_k, \theta_{kh}$ are parameters to be estimated.

Define $S_j = P_j X_j / \pi'$ as the ratio of variable expenditures for the ith input relative to restricted profit. Let $S_y = Y / \pi'$ be the ratio of output supply (Y) to normalized, restricted profit. S_y is also equivalent to the ratio of the total value of output to restricted profit. Differentiating the translog profit function (3.20) with respect to $\ln P_i$ and $\ln P_y$ gives a system of variable input/profit ratio functions and an output supply/ profit ratio functions (Diewert, 1974; Christensen *et al.*, 1973) as shown in equations 3.21 and 3.22 respectively:

$$S_i = \frac{P_i X_i}{\pi'} = -\frac{\delta \ln \pi'}{\delta \ln P_i} = -\alpha_i - \sum_{k=1}^{5} \gamma_{ij} \ln P'_j - \sum_{l=1}^{6} \delta_{il} \ln Z_k \quad (3.21)$$

$$S_y = \frac{P_y Y}{\pi'} = 1 + \frac{\delta \ln \pi'}{\delta \ln P_y} = 1 - \sum_{j=1}^{5} \alpha_i - \sum_{i=1}^{5} \sum_{k=1}^{5} \gamma_{ij} \ln P'_j - \sum_{l=1}^{6} \delta_{ik} \ln Z_k \quad (3.22)$$

where S_i is the share of ith input, S_y is the share of output, X_i denotes the quantity of input i and Y is the level of liquid milk output. Since the input and output shares form a singular system of equations (by definition $S_y - \sum S_i = 1$) one of the share equations, the output share, is dropped and the profit and factor demand equations for protein feeds, roughage feeds, animal treatment, tick administration, and labour are estimated as a simultaneous system. Under the liberalized environment of the dairy farms, the normalized input prices and quantities of fixed factors are considered to be the exogenous variables. In terms of the regularity properties of the profit function, homogeneity is automatically imposed because the normalized specification is used. The convexity property is assumed to hold and is not tested. But the symmetry restriction will be formally tested in this study.

3.4.2. Estimation of Production Elasticities

The parameter estimates of equations 3.20 and 3.21 will be used to estimate the elasticities related to variable input demands, output supply and the profit function. These elasticity estimates represent the structure of supply response for the dairy farms in the marginal areas. They are policy variables which indicate different impacts that exogenous variables have within and across input demand and output supply functions. They are evaluated at averages of the S_i and at given levels of variable input prices (for the case of variable factors) are linear transformations of the parameter estimates of the profit function. These elasticities will be obtained using the following formulae (see Sidhu & Baanante, 1981; Farooq *et al.*, 2001):

The own-price elasticity of demand for variable input i (η_{ii}) is estimated as:

$$\eta_{ii} = -S_i - \frac{\gamma_{ii}}{S_i} - 1 \tag{3.23}$$

where S_i is the ith share equation, at the sample mean. For the cross-price elasticity of demand for ith variable input with respect to the price of jth variable input (η_{ij}), the following expression will be used with respect to output price:

$$\eta_{ij} = -S_j - \frac{\gamma_{ij}}{S_i} \text{ for } i \neq j \tag{3.24}$$

The following equation will be used for estimating the elasticity of demand for variable input with respect to output price, P_y, (η_{iy}):

$$\eta_{iy} = S_y + \sum_{j=1}^{5} \frac{\gamma_{ij}}{S_i} \tag{3.25}$$

where S_y is the output share, at the sample mean. Finally, the elasticity of demand for variable input with respect to kth fixed factor, (η_{ik}), will be determined as:

$$\eta_{il} = \left(\beta_k + \delta_{ik} \ln P_i + \sum \theta_{kh} \ln Z_h \right) - \frac{\delta_{ik}}{S_i} \tag{3.26}$$

The own-price elasticity of supply, η_{yy}, is determined as:

$$\eta_{yy} = \sum_{i=1}^{5} S_i + \frac{\sum_{j=1}^{5} \gamma_{ij}}{S_y} \tag{3.27}$$

whereas the elasticity of output supply with respect to price of ith variable output η_{yi} is given by:

$$\eta_{yi} = -S_i - \frac{\sum_{j=1}^{5} \gamma_{ji}}{S_y} \tag{3.28}$$

The elasticity of output supply with respect to fixed input $k, (\eta_{yk})$ is computed as:

$$\eta_{yk} = \left(\beta_k + \sum_{i=1}^{5} \delta_{ik} \ln P'_i + \sum_{h}^{m} \theta_{kh} \ln Z_h \right) + \frac{\sum_{i=1}^{5} \delta_{ik}}{S_y} \tag{3.29}$$

Finally the profit elasticities are defined as:

$$\frac{\partial \ln \pi^*}{\partial \ln P_i^*} \quad \text{and} \quad \frac{\partial \ln \pi^*}{\partial \ln Z_k} \tag{3.30}$$

for the elasticity of profit with respect to changes in input prices and for the profit elasticity with respect to changes in fixed inputs respectively.

3.4.3. Hypothesis Testing

Four formal statistical tests will be done in this section. They are conducted to test for the validity of the symmetry and parametric constraints across profit and input demands i.e. S_i equations. These are joint hypotheses on the validity of imposing restrictions to estimate the equations simultaneously as a system. The WALD test which has good asymptotic properties is conducted to test these hypotheses. The results are discussed in Chapter 6.

3.5. Data Sources and Collection

The primary data for the study pertains to an intensive farm-survey of smallholder dairy producers conducted during June-September 2006 in five dairy cooperative societies in the marginal zones of Machakos and Makueni Districts. A structured questionnaire instrument was used for data collection. Trained graduates with a degree in an agricultural related field gathered data via person-to-person interviews under the supervision of the researcher and an experienced research assistant from Tegemeo Institute of Agricultural Policy and Development. Information gathered included both quantitative and qualitative forms of data from dairy farms. These included structure of dairy herd, annual milk production, sales and sales outlet prices on monthly basis, grazing land and acreage for fodder production, dairy management information, dairy breeding service markets & annual expenditures, animal health service markets & annual expenditures, purchased feeds used & their prices, local feeds markets, quantities fed and their respective prices, annual labour use in dairy and wage rates. Other information included credit availability, water availability and extension visits.

To capture both the dairy society and inter-farm difference, a two stage random sampling strategy was adopted. First a random sample of five of 6 dairy societies in the marginal zones of Machakos and Makueni Districts was undertaken. These five societies were Kilungu, Kikima, Masii, Wamunyu and Makueni. Each one of them was visited and a list of all members and their registration numbers ascertained. There were 891 active smallholder dairy farmers in the five cooperative societies (Table 3.1). A proportionate sample of active dairy farmers was randomly selected from each dairy society as shown.

Table 3.1: Number of Dairy Farmers Selected for the Study

Items	Dairy Cooperatives in the marginal zones of Machakos District.		Dairy Cooperatives in the marginal zones of Makueni District.			Total
	Wamunyu	Masii	Kikima	Kilungu	Makueni	
Total number of dairy members	385	450	525	400	517	2277
Number of active members	187	288	131	116	169	891
Number of farmers selected for the study	60	92	42	37	54	285

Source: Sample Survey of Dairy Households in the Marginal zones of Kenya, June-September, 2006.

Overall, 285 dairy farms out of 891 in all the five societies were selected for the study. The survey data collected was used to create the appropriate variables for the analysis in the respective analytical models. Households with dairy cows greater than 15 were considered as outliers and were excluded from this study.

The descriptive statistics for the survey data are presented in Table 3.2. The average annual milk yield per cow is 1424.88 litres. It is lower than the annual milk yield of 1923 litres of the smallholder dairy in the high potential areas of Kiambu (Kilungo, 1999). The corresponding use of variable inputs contributing to this milk yield level was 1.33 kg of milking salve, 16.04 kg of mineral salts, 1322.10 man-hours, 4.86 acres of grazing land and 6.82 tons of own produced feeds (which included: farm by-products, Napier grass and other grasses). 63.51 percent (i.e. 181 farmers) of the farmers purchased concentrates whereas 38.25 percent (i.e. 109 farmers) purchased hay from the formal input markets for animal feeds. 68.77 percent (196 farmers) of the farmers purchased feeds in the local markets i.e. within the local villages and the neighbourhood areas. This is an indication that local animal feeds markets are getting established in this area; where farmers without dairy cows can grow animal feeds such as Napier grass, natural grass and farm by-products and sell them to those who keep dairy cows or dairy farmers with excess feeds can sell them to others. The average age of the household dairy managers was 50.19 years. 52 percent of them are aged below 50 years old. 88.1 percent of the dairy managers have an experience of 5 years and above in dairying, and 21.1 percent of them are involved in off-farm employment. 9.8 percent of the managers have no formal education, 49.5 percent have primary school education, 30.3 percent have high school education, 8.5 percent middle college training and 2 percent college education.

Table 3.2: Descriptive Statistics of the Survey Data

Variable Description	Measuring Units	Mean	Std. Deviation	Coefficient of variation (%)	Cases
Milk quantity produced per cow	Liters	1424.88	918.94	64.4924	285
Milk salve per cow	Kilograms	1.33	4.65	249.6241	242
Mineral salt per cow	Kilograms	16.04	23.76	148.1297	245
Concentrate per cow	Kilograms	423.53	367.65	86.8061	181
Local feed purchases per cow	Kilograms	1436.34	1480.31	103.0613	196
Hay purchases per cow	Kilograms	667.82	933.68	139.8101	109
Man-hours per cow	Man-hours	1322.10	874.98	66.1811	285
Grazing area	Acres	4.86	5.02	103.2922	252
Own produced feeds per cow	Tons	3.48	4.11	118.1034	276
Milk outlet weighted price per kg	Kshs/kg	18.94	3.67	19.3770	283
Milking serve price per kg	Kshs/kg	378.33	202.90	53.6304	242
Mineral salt price per kg	Kshs/kg	67.90	38.31	56.4212	245
Hay price per kg	Kshs/kg	12.02	2.86	23.7937	109
Concentrate price per kg	Kshs/kg	14.85	2.93	19.7306	181
Local feed price	Kshs/kg	4.62	5.65	122.2944	196
Breeding price per service	Kshs/service	533.91	338.03	63.3122	141
Breeding price per cow	Kshs/cow	674.63	551.46	81.7426	141
Tick control price/administered	Kshs/service	33.58	22.89	68.1656	284
Tick control price per cow	Kshs/adm	846.94	1009.56	119.2009	284
Treatment price per administration	Kshs/service	476.59	663.22	139.1594	271
Treatment price per cow	Kshs/cow	770.54	1227.91	159.3571	270
Wage rate per hour	Kshs/hour	7.70	2.80	36.3636	283
Age of dairy manager	Years	50.19	15.81	31.5003	285
Manager's years of schooling	Years	8.02	4.24	52.8678	285
Manager's years of experience	Years	16.66	12.21	73.2893	284
Number of Extension visits	Count	2.80	3.17	113.2143	285
Number of dairy cows	Count	2.78	2.71	97.4820	284
Farm records	1=yes, 0=no	0.39	0.49	-	285
Feed storage	1=yes, 0=no	0.91	0.28	-	285
Farm to water point distance	Kilometers	0.53	0.74	139.6226	285
Use of credit	1=yes, 0=no	0.52	0.50	-	285

Table 3.2 (continued)

Variable Description	Measuring Units	Mean	Std. Deviation	Coefficient of variation (%)	Cases
Off-farm employment	1=yes, 0=no	0.21	0.31	-	285
Agro-Ecological zone	1=IV, 0=III&II	0.72	0.45	-	285

Source: Sample Survey of Dairy Households in the Marginal zones of Kenya, June-September, 2006.

The main breed composition in the dairy hard structure was: 80.2 percent Friesian for 182 households, 59.7 percent Ayrshire in 52 households, 55.4 percent Guernsey in 19 households, 62.5 percent Jersey in 24 households , 65.1 percent Sahiwal in 47 households , 76.8 percent Boran in 15 households, 70.8 percent zebu in 22 households, and 72.9 percent zebu upgrades in 34 households. The main dairy breeds kept by the households were 54.7 percent Friesians, 9.5 percent Ayrshire, 2.8 percent Guernsey, 4.9 percent Jersey, 9.1 percent Sahiwal, 3.5 percent Boran, 5.3 percent Zebu and 10.2 percent Zebu upgrades. 71.9 percent of the households keep exotic breeds (Friesian, Ayrshire, Guernsey and jersey) and of these, 64.2 percent of the households mainly keep large breeds (Friesians and Ayrshire). These statistics indicate that the large breeds predominate in both the numbers of the households keeping them as well as in the composition of the dairy hard structure in the marginal zones.

The grazing systems practised are: 11.2 percent zero grazing, 85.3 percent semi-zero grazing and 3.5 percent field grazing. 23.9 percent of the households used Artificial Insemination (AI), 62.8 percent used bull service and 13.3 used both AI and bull service for cow breeding in the year preceding the survey. The low use of AI can perhaps be explained by the relatively high costs of the service ranging between Kshs. 500 to Kshs. 3000 as compared to that of the bull service which ranges between Kshs 40 and Kshs 500. The repeated use of bull service increases in-inbreeding in the cow hard and ultimately results in low milk production. In addition, 38.9 percent of the households keep dairy records, 90.9 percent store animal feeds, 51.9 percent received credit for dairying activities, 48.1 percent have water for dairy cattle on their farms, and the distance from the households to the water point for the dairy cattle ranges between 0 to 5 kilometres.

A Global Positioning System (GPS) was used to get the locations of the selected farms, dairy cooperative societies and veterinary animal health service provider positions. Figure 3.1 shows a GPS map of the study area and the respective positions of farms, dairy societies and the veterinary animal health service providers. The GPS map was used to measure the distances of the dairy farms to the nearest animal health service provider, cooperative society, the nearest usable weather road from the household and the distances to the tarmac road. These distances represent the road infrastructure within which the dairy farmers operate. Table 3.3 shows the descriptive statistics of road infrastructure distances with respect to the surveyed dairy households. The average household distances to the cooperative society and to the nearest veterinary animal health provider is nearly the same because both of them are located in township centres. As the farmers deliver milk to the cooperative societies or to the hotels, they can also get health services from the animal health providers, consult with them or arrange for a visit. However, the distances from the household to the nearest weather road and to the nearest tarmac road differ. If the distance from the household to the nearest weather road is relatively long compared to the distance from the household to the tarmac road, dairy operations are expected to be constrained. It

Figure 3.1: A GPS Map Showing the Households, Dairy Cooperatives and the Veterinary Animal Health Service Providers in the Marginal Zones.

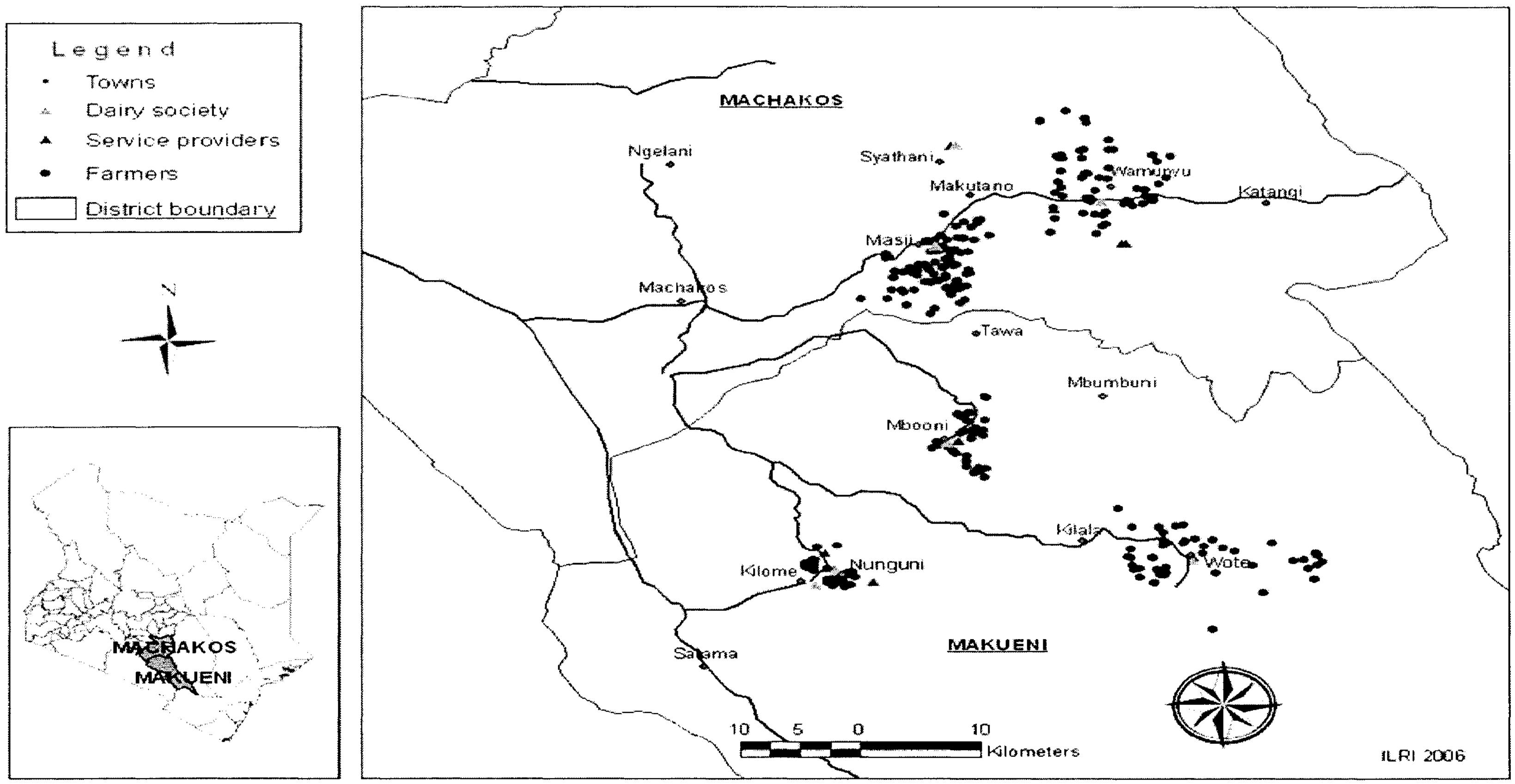


Table 3.3: Road Infrastructure Distances in Relation to Dairy Households

Distances	Unit of Measurement	Mean	Std. Deviation	Coefficient of variation (%)
Household distance to tarmac road	Kilometers	6.08	6.54	107.56
Household distance to a weather road	Kilometers	2.34	2.39	102.13
Household distance to the nearest service provider	Kilometers	3.56	2.46	69.10
Household distance to dairy cooperative society	Kilometers	3.73	2.18	58.44
Ratio of walking to tarmac distance	Kilometers	0.55	0.40	72.72

Source: Sample Survey of Dairy Households in the Marginal zones of Kenya, June-September, 2006.

implies that the farmer has to walk for a long distance to get to the tarmac road when delivering milk and also when carrying purchased dairy feeds to the homestead. The animal health service providers also have to walk long distances when conducting dairy hard visits. Expectations are that the walking distance would tend to slow down dairy operations. The ratio of the walking distance from the homestead to a motorable road and the distance from home to the tarmac road ranges between 0 and 1 (Table 3.3). It is 0 if the farmer is served by a motorable road or situated on the tarmac road and 1 if the farmer walks the whole distance to the tarmac road. As at the time of the survey, there was no tarmac road in Mbooni. So, the main weather road which is hear-marked for construction was used as a proxy for a tarmac road in the area. The average ratio of the walking distance to the distance from the homestead to the tarmac road for all the surveyed households was 0.55.

CHAPTER IV

MEASUREMENT OF COST EFFICIENCY IN SMALL SCALE DAIRY FARMS

4.1. Introduction

This chapter uses a cost function approach and combines the concepts of technical and allocative efficiency in the dairy cost relationship. Any errors in production decision translate into higher costs for the producer. At the same time, the stochastic nature of production implies that the theoretical cost function is stochastic. A one step process was used to estimate cost efficiency using the Maximum Likelihood method in Limdep (Green, 2002). The chapter highlights different models considered in the analysis as well as model results under the assumption of half-normal and exponential distributions of the error term. It also presents results from testing and correction of heteroscendasticity, orthogonality condition and hypotheses testing. Individual farm level cost inefficiency is also estimated and discussed.

4.2. Data and Variable Definitions

The variables used in cost efficiency analysis were created from the survey data described in Chapter 3 Section 3.5. The dependent variable is the natural logarithm of the total variable costs (LNCOST) of milk production for the period July 2005 to June 2006. The total variable cost is a sum of expenditures for concentrates, mineral salts, milking serve, hay, locally purchased feeds (i.e. Napier grass, maize stover and other grasses), tick control, cattle treatment and labour.

The independent variables used in estimating the stochastic frontier translog cost function were natural logarithms of milk output value, price of animal feeds, price of animal health, labour wage rate, and quantity of own produced feeds as well as areas of dairy grazing as fixed inputs. Milk output value variable (LNQNT) was computed by multiplying the total milk produced in the year by a weighted milk price. Price weighting was done for each household with respect to the milk quantities marketed through different channels (i.e. cooperative, neighbours, hawkers and local hotels/kisosks/schools etc.). To compute the price of feeds (LNFDP) variable, the total expenditures and quantities for each respective feed was obtained for each household. The price was then obtained by dividing expenditure with the respective quantities of feed purchased in the year. The prices were added together across the feeds and a natural logarithm was obtained for the price of a bundle of feeds. The feeds included were concentrates, mineral salts, milking salve, hay and locally purchased feeds.

The Price of animal health variable (LNHELP) was created by dividing the annual expenditure on tick control and cow treatment by the total number of the respective administrations, to get price per treatment. The two prices were added together and the natural logarithm was computed for the total price of animal health treatment. The labour wage rate (LNWAGE) was computed by following the procedure used by other studies (Karanja, 2002; Kilungo, 1999; and Lau and Yotopoulos, 1971). The total annual expenditure of both family and hired labour on dairy cattle and the total number of person hours were computed. A division between these two variables resulted in the prevailing wage rate per hour in each household. The expenditures on family labour were based on an imputed opportunity cost wage of working on the dairy enterprise. All of the above four variables were expected to have positive effect on the dependent variable. The fixed costs included in the analysis were own produced feeds (LNPRDFD) [composed of home grown Napier grass, maize stover and other grasses] and area of dairy cattle grazing (LNACRE).The rest of the variables in the stochastic frontier model (see equation 5.1) are squared and cross terms of these six variables.

In the inefficiency model, several variables were hypothesised as being responsible for the estimated farm-specific cost inefficiencies. These variables are presented in Table 4.1.

Table 4.1: Definition of Variables Hypothesised as Accounting for Cost Inefficiency

Variable	Description
AGE	Age of the dairy manager (years)
SCHED	Years of schooling (for dairy manager)
SQYRED	Square of years of schooling
EXP	Years of dairying experience
EXNTV	Number of extension visits
NUMCOW	Number of milking cows
RECODS	Dummy variable=1 if farmer kept dairy records and 0 otherwise
FDSTO	Dummy variable=1 if farmer stored feeds on farm and 0 otherwise
H20DS	Distance from farm to the water point for cattle (Kilometers)
CREDIT	Dummy variable=1 if farmer used credit and 0 otherwise
OFARM	Dummy variable=1 if dairy manager had off-farm employment and 0 otherwise
WLKMODR	Ratio of walking distance to the tarmac distance from homestead
AEZ	Dummy variable=1 for transitional zone IV and 0 otherwise

On a *priori* basis, the age education level and years of experience of the dairy manager are expected to have a positive effect on the level of efficiency as they embody strength and skills which can improve economic efficiency. The *a priori* expectation is that the level of market integration in dairy production would increase efficiency as it allows a household to acquire market information that enables it to have higher allocative efficiency. Furthermore, most of the dairy inputs and dairy production technologies are interlocked with milk markets and they embody the number of milk cows kept. As such, the number of milk cows is expected to be positively related with efficiency. The availability of extension and credit, keeping of records and storage of feeds are expected to increase efficiency. The distance from the farm to the watering point is expected to decrease efficiency. However, no *a priori* expectation could be placed on off-farm employment. Engagement in off-farm income generating activities can reduce the amount of labour available for on-farm production. Nevertheless, income from off-farm activities can be used to purchase inputs and hiring of labour thereby enhancing efficiency.

The ratio of the walking distance from homestead to the whole distance from homestead to the tarmac road is the section of the road infrastructure which is expected to influence efficiency. Expectations are that a higher ratio of the walking distance would decrease efficiency. Farmers in Mbooni and Kilungu hilly land masses are within the Agro-Ecological zone (AEZ) UM II and UM III. The climate in this zone is relatively cool and wet and is more suitable for exotic dairy cattle than the transitional marginal zone VI which is relatively hot and dry. Therefore, keeping dairy cows in AEZ VI is expected to reduce efficiency.

The inefficiency model with the respective variables is presented in the stochastic frontier translog cost function as Rh2 in equation 4.1.

FRONTIER;Lhs=LNCOST;**Rhs**=β_o + β_1LNQNT+ β_2LNFDP+ β_3LNHELP+ β_4LNWAGE+β_5SQQNT+ β_6SQFD + β_7SQHEL+ β_8SQWAGE+ β_9QNTFD+ β_{10}QNTHEL+ β_{11}QNTWAG+ β_{12}FDHEL+ β_{13}FDWAG+β_{14}HELWAG+ β_{15}QNTPRD+ β_{16}QNTACR+ β_{17}FDPRD+ β_{18}FDACR+ β_{19}HELPRD+ β_{20} HELACR+ β_{21}WAGPRD+ β_{22}WAGACR+ β_{23}PRDFD+ β_{24}ACRE+ β_{25}SQPRDFD+ β_{26}SQACRE+ β_{27}PRDACRC;**Rh2**=α_0 + α_1AGE+ α_2SCHED+ α_3SQYRED+ α_4EXP+ α_5EXNTV+ α_6NUMCOW+ α_7RECODS+ α_8FDSTO+ α_9H2ODS+ α_{10}CREDIT+ α_{11}OFARM+ α_{12}WLKMODR+ α_{13}AEZ;Cost$ (4.1)

4.3. The Stochastic Frontier Cost Model Results

Table 4.4 shows the estimated original model before the data was transformed (corrected for heteroscendasticity and multicollinearity). Most variables in the stochastic frontier model and a few in the inefficiency model are significant. However, lambda λ (where $\lambda = \sigma^2_u / \sigma^2$) is statistically significant . This implies that there are measurable inefficiencies in dairy production probably occasioned by differences in institutional and socioeconomic factors.

4.3.1. Heteroscedasticity Test

Heteroscedasticity is a violation of one of the requirements of ordinary least squares (OLS) in which the error variance is not constant. The consequence is that the estimated coefficients are unbiased but inefficient. The variances are either too small or too large. This leads to Type I[4] or Type II errors. In the presence of heteroscendasticity, OLS is not Best Linear Unbiased Estimator (BLUE). Heteroscedasticity is prevalent in cross-sectional data set such as the one currently under use in this study. It occurs when:- variance of the dependent variable increases with increase in the level of independent variable, variance of dependent variable decreases with increases in independent variable and also it can occur as a result of the presence of outliers in the data set.

The heteroscendasticity model formulation of the stochastic frontier was used to test for the presence of heteroscedasticity in the cost frontier and the inefficiency models. The hereoscedasticity function (*hfv*) which captures the variance emanating from the normal error term v , and the heteroscedasticity function (*hfu*) which captures variances in the truncated half normal error term u were added and analysed in the stochastic frontier and the inefficiency model as shown in equation 4.2. The results revealed that the p-values of some of the variables in the *hfu* function were statistically significant. This implied that

---

4 Type I error, leads to rejection of a true Null hypothesis, while in Type II error, one accepts a false Null Hypothesis there was single heteroscedasticity emanating from the inefficiency error term.

```
FRONTIER;Lhs=LNCOST;Rhs=ONE,LNQNT,LNFDP,LNHEL,LNWAGEP,SQQNT,SQFD,SQHEL,
SQWAG,QNTFDC,QNTHELC,QNTWAGC,FDHELC,FDWAGC,HELWAGC,QNTPRDC,QNTACRC
,FDPRDC,FDACRE,HELPRDC,HELACRC,WAGPRDC,WAGACRC,LNPRDFD,LNACRE,SQPRDFD
,SQACRE,PRDACRC,;Rh2=ONE,FMAGE,FMSCH,SQYREDU,YRSEXP,EXNTVIS,TOTCOW
,RECODS,FDSTORE,CREDIT,H2ODS,OFARM,WLKMODR,AEZ;Het;Hfu=ONE,FMAGE,FMSCH
,SQYREDU,YRSEXP,EXNTVIS,TOTCOW,RECODS,FDSTORE,H2ODS,OFARM,WLKMODR,AEZ
;Cost$                                                            (4.2)
```

4.3.2. Breusch-Pagan Test for Heteroscedasticity and Correction

The Breausch–Pagan test procedure was used to confirm the implied presence of heteroscedasticity in the above mentioned test and to correct it. The steps of performing this procedure are:

1) Estimate: LNCOST= $\beta_0 + \beta_1 X_{1k} + \beta_2 X_{2k} + ... + \beta_k X_{ik} + e_i$ by OLS and obtain the residuals e_i.

2) Obtain $\tilde{\sigma}^2 = \sum e_i^2 / N$ [where $\tilde{\sigma}^2$ is the maximum likelihood (ML) estimator of σ^2)

3) Construct $\hat{V}_i^2 = \sum e_i^2 / \sigma^2$

4) Regress $\hat{V}_i^2$ thus constructed on Z's (the dependent variables)

5) Then obtain R^2

For large samples, the product of R-squared and the sample size follows a Chi-square distribution: (N-P)* $R^2 \sim \chi_P^2$, where P is the number of dependent variables in the regression.

In this analysis, the computed Chi-square is 245.1742. The degrees of freedom (df) for this case is 39 (i.e. 40-1). The critical Chi-square (at df =40, 5 percent) is 55.7585. Since the computed Chi-square is greater than the critical Chi-square, the null hypothesis of homoscedasticity is rejected and it is concluded that there is heteroscedasticity in the model.

There are several methods of correcting for heteroscedasticity such as the transformation of the data into natural logarithms and the Generalized Least Squares (GLS), also known as the weighted Least Squares (WLS). If σ^2 is known, the most straightforward method of correcting heteroscedasticity is by means of WLS method for the estimators thus obtained are BLUE (Gujarati, 2003). In this case, the weighting factor ($1/\sigma$) is calculated by obtaining the reciprocal of (σ) i.e. the square root of the estimated model variance (σ^2) from step (2). Then, all the variables in the stochastic frontier model are multiplied by this function as shown in equation 4.3.

```
[LNCOST;Rhs=ONE,LNQNT,LNFDPC,LNHELP,LNWAGEP,SQQNT,SQFD,SQHEL,SQWAGE
,QNTFDC,QNTHELC,QNTWAGC,FDHELC,FDWAGC,HELWAGC,QNTPRDC,QNTACRC,FDPRDC
,FDACRE,HELPRDC,HELACRC,WAGPRDC,WAGACRC,LNPRDFD,LNACRE,SQPRDFD,SQACRE
,PRDACRC,FMAGE,FMSCH,SQYREDU,YRSEXP,EXNTVIS,TOTCOW,RECODS,FDSTORE,H20DS
,CREDIT,OFARM, WLKMODR AEZ]*1/σ                                    (4.3)
```

The transformed variables are then orthogonalized to remove multicollinearity and then used in subsequent analysis. Correcting for heteroscedasticity improves precision of the beta coefficients and estimated mean cost efficiency.

4.3.3. Orthogonality Condition

The orthogonality condition requires a linear independent relationship between the independent variables and the error term. If this condition is not met, then the results of the stochastic frontier are usually biased. In OLS, it is assumed that the covariance between the independent variables and the error term is zero i.e. cov(x_i,e_i) =0. However, since the estimation of the stochastic frontier cost function is based on the distribution of the error term, it is prudent to ensure that variables measuring inefficiency are independent from the variables in the stochastic frontier. The process is performed by regressing the individual variables in the inefficiency model e.g. years of dairy experience on the stochastic frontier cost model variables (equation 4.4.).

```
REGRESS;Lhs=HYRSEXP;Rhs=ONE,HLNQNT,HLNFDPC,HHEL,HWAGEPC,HSQQNT,HSQFD
,HSQHEL,HSQWAGE,HQNTFD,HQNTHEL,HQNTWAG,HFDHEL,HFDWAG,HHELWAG,HQNTPRD
,HQNTACR,HFDPRD,HFDACR,HHELPRD,HHELACR,HWAGPRD,HWAGACR,HPRDFD,HACRE
,HSQPRDFD,HSQACRE,HPRDACRC;Res=eHYRSEXP$
```
(4.4)

A high R-squared for the regression indicates a high dependence between the inefficiency model variables i.e. years of dairy experience and variables in the stochastic frontier model. Table 4.2 summarises the R-squared values for the inefficiency model variables considered to be explaining inefficiency in dairy production in the marginal zones. The results in the table indicate that most variables in the inefficiency model have a low covariance with the

Table 4.2: Orthogonality Test

Variable	Variable Label	R-Squared
HAGE	Age of Dairy Manager	0.1890
HSCHED	Manager's years of schooling	0.1560
HYRSEXP	Years of experience in dairy	0.0954
HEXNTV	Number of extension visits	0.3402
HNUMCOW	Number of dairy cows kept	0.7498
HRECODS	keeping of dairy records	0.2475
HFDSTO	Feed storage on farm	0.3809
HH20DS	Distance to water point	0.1807
HCREDIT	Used credit	0.3539
HOFARM	Off-farm employment	0.0760
HWLKMODR	Ratio of walking distance to tarmac distance	0.2535
HAEZ	Agro-ecological zone	0.6925

Source: Sample Survey of Dairy Households in the Marginal zones of Kenya, June-September, 2006.

stochastic model. However, in order to ensure that the independent variable and the error term have no linear relationship, the residuals (e_i) of the respective regressions are used in the estimation of cost efficiency. Among the inefficiency variables, age of the farm manager and years of experience were found to be highly correlated (r=0.581). Each of the two variables was regressed on the rest of the inefficiency variables and their respective residual errors were used as their proxies in the analysis. After all the various data transformations needed to take care of heteroscedasticity, high correlation and ensure orthogonality condition, equation 4.1 is then estimated. The data is analysed using the translog cost frontier under assumptions of half normal, exponential, and truncated normal inefficiency error distributions. Also an analytical attempt was made on different functional forms of the cost function i.e. translog, quadratic and Cobb-Douglas cost functions. The model estimation results are discussed in section 4.4.

4.4. Model Estimation and Results

Table 4.3 shows results of the stochastic frontier final models for Translog and Cobb-Douglas functional forms. Most of the independent variables in the stochastic frontier model have the expected signs and are significant. However, the value of milk output has a negative sign. A possible explanation for this result is that agricultural production costs of food commodities are high relative to output values because of low yields, high input prices, poor infrastructure and several indirect charges on farmers' income in addition to a high tax rate on most agricultural commodities (Nyoro *et al.*, 2004). Karanja (2002) reported a similar finding in a cost efficiency study of coffee farmers in the central province of Kenya, where the output value had a negative and a significant effect on cost of production. The mean cost efficiency is computed for each model. The estimated

Table 4.3: Translog and Cobb-Douglas Cost Functional Forms of Stochastic Frontier

Variable Name	Variable Label	Parameters	Translog Model	Cobb-Douglas Model
Stochastic Frontier				
LNQNT	Constant	β_o	6.8806***	30.6632***
LNFDP	Milk output	β_1	-0.1692***	-0.0032
LNHELP	Feed price	β_2	0.0003	0.0006
LNWAGE	Health price	β_3	0.2968***	0.0079
SQQNT	Wage	β_4	1.2598***	0.0069***
SQFD	Milk output* milk output	β_5	0.0308***	
SQHEL	Feed price*Feed price	β_6	0.0049	
SQWAGE	Health price *Health price	β_7	0.0011	
QNTFDC	Wage * Wage	β_8	-1.5289***	
QNTHELC	Milk output*feed price	β_9	0.0095	
QNTWAGC	Milk output*health price	β_{10}	0.0146	
FDHELC	Milk output* Wage	β_{11}	0.2569***	
FDWAGC	Feed price*health price	β_{12}	0.0034	
HELWAGC	Feed price *wage	β_{13}	-0.0463*	
QNTPRDC	Health price*Wage	β_{14}	0.0418*	
QNTACRC	Milk output*Produced feed	β_{15}	-0.0810***	
FDPRDC	Milk output* Grazing acres	β_{16}	-0.0606***	
FDACRE	Feed price* produced feed	β_{17}	-0.0005	
HELPRDC	Feed price* Grazing acres	β_{18}	0.0099	
HELACRC	Health price* produced feed	β_{19}	0.0044	
WAGPRDC	Health price* Grazing acres	β_{20}	-0.0012	
WAGACRC	Wage* produced feed	β_{21}	0.0756*	
LNPRDFD	Wage* Grazing acres	β_{22}	-0.0810	
LNACRE	Produced feed	β_{23}	0.7114***	-0.0023***
SQPRDFD	Grazing acres	β_{24}	0.7977***	-0.0018
SQACRE	Produced feed* Produced feed	β_{25}	-1.3917***	
PRDACRC	Grazing acres* Grazing acres	β_{26}	0.0438***	
LNQNT	Produced feed* Grazing acres	β_{27}	0.6820***	
Inefficiency Model				
Constant	Constant	δ_0	6.8463**	4.2005*
AGE	Age of manager	δ_1	0.0178*	0.0134*
SCHED	Years of School	δ_2	0.1154**	0.1337**
SQYRED	Years of School* Years of School	δ_3	-0.0087**	-0.0087**
EXPER	Dairy Experience	δ_4	-0.0008	-0.0006
EXNTV	Number of Extension visits	δ_5	-0.0130*	-0.0214***
NUMCOW	Number of milk cows	δ_6	-0.0058	-0.0146
RECODS	Dairy Records	δ_7	-0.4116**	-0.6570***
FDSTO	Feed storage	δ_8	-0.4799	-0.3063
H20DS	Distance to water point	δ_9	-0.0157	0.0201
CREDIT	Used Credit	δ_{10}	-0.4251*	-0.3693*
OFARM	Off-Farm employment	δ_{11}	0.1924	0.0562
WLKMODR	Walking distance to tarmac ratio	δ_{12}	0.6002**	0.4621**
AEZ	Agro-ecological zone	δ_{13}	-1.2248***	-0.9888***

Table 4.3 (Continued)

Variable Name	Variable Label	Parameters	Translog Model	Cobb-Douglas Model
Variance Parameters				
Lambda	Lambda = σ_u / σ_v	λ	3.6999***	2.0809***
Sigma	Sigma = $\sqrt{(\sigma_v^2 + \sigma_u^2}$	σ^2	1.7922***	2.3938***
Sigma(v)	Sigma(v)	σ_v	.46761	1.03683
Sigma(u)	Sigma(u)	σ_u	1.73013	2.15758
Sigma-squared (v)	Sigma-squared (v)	σ_v^2	.21866	1.07501
Sigma-squared (u)	Sigma-squared (u)	σ_u^2	2.99334	4.65515
Gamma	Gamma	γ	0.9319	0.8124
Log likelihood	Log likelihood		-389.2387	-565.7207
Cost Efficiency	Cost Efficiency		27.4501%	12.0452%

Source: Source: Sample Survey of Dairy Households in the Marginal zones of Kenya, June-September, 2006.
* Significant at 10% level (p< 0.10)
** Significant at 5% level (p<0.05)
*** Significant at 1% level (p<0.001)

mean cost inefficiency is 27 percent for translog model and 12 percent for Cobb-Douglas model. The quadratic model formulation had no measurable inefficiencies. The transcendental functional form could not be estimated because OLS residuals have wrong skew. Therefore, OLS is MLE (Green 2002). Hence , the results and discussions focus on the translog cost function because of its flexibility as compared to the restrictive Cobb-Douglas functional form. The translog cost frontier has been used in recent stochastic production frontier studies by Karanja (2002) and Pariksh *et al.* (1995). In the section which follows, a log likelihood ratio test is carried out to determine if the dairy farmers in the marginal zones exhibit a Cobb-Douglas or a translog production cost frontier.

Table 4.4 presents additional results of the Maximum Likelihood (ML) estimates of the translog cost frontier models under the assumptions of half-normal and exponential distributions of the error terms. The cost frontier model with truncated half-normal distribution of the error terms were also estimated for comparison purposes. The results of

Table 4.4: Maximum Likelihood Estimates of the Translog Cost Frontier and Inefficiency Model

Variable Name	Variable Label	Parameters	Original model Half-Normal Model	Final Model Half-Normal Model	Final Model Exponential Model
Stochastic Frontier					
Constant	Constant	β0	1.8843**	6.8806***	2.0986***
LNQNT	Milk output	β1	-0.2076***	-0.1692***	-0.1739***
LNFDPC	Feed price	β2	0.0004	0.0003	0.00001
LNHELPC	Health price	β3	0.2092**	0.2968***	0.2848***
LNWAGEPC	Wage	β4	1.2877***	1.2598***	1.2670***
SQQNT	Milk output* milk output	β5	0.0282**	0.0308***	0.0305***
SQFD	Feed price*Feed price	β6	0.0075	0.0049	0.0048
SQHEL	Health price *Health price	β7	0.0021	0.0011	0.0014
SQWAGE	Wage * Wage	β8	-1.5151***	-1.5289***	-1.5147***
QNTFDC	Milk output*feed price	β9	0.0076	0.0095	0.0083
QNTHELC	Milk output*health price	β10	0.0040	0.0146	0.0134
QNTWAGC	Milk output* Wage	β11	0.2981***	0.2569***	0.2622***
FDHELC	Feed price*health price	β12	0.0040	0.0034	0.0030
FDWAGC	Feed price *wage	β13	-0.0474*	-0.0463*	-0.0424
HELWAGC	Health price*Wage	β14	0.0460*	0.0418*	0.0410*
QNTPRDC	Milk output*Produced feed	β15	-0.0699***	-0.0810***	-0.0798***
QNTACRC	Milk output* Grazing acres	β16	-0.0604***	-0.0606***	-0.0605***
FDPRDC	Feed price* produced feed	β17	0.0001	-0.0005	0.0005
FDACRE	Feed price* Grazing acres	β18	0.0112	0.0099	0.0101
HELPRDC	Health price* produced feed	β19	0.0047	0.0044	0.0047
HELACRC	Health price* Grazing acres	β20	0.0020	-0.0012	-0.0012
WAGPRDC	Wage* produced feed	β21	0.0162	0.0756*	0.0648
WAGACRC	Wage* Grazing acres	β22	-0.0924*	-0.0810	-0.0849*
LNPRDFD	Produced feed	β23	0.7054***	0.7114***	0.7136***
LNACRE	Grazing acres	β24	0.7615***	0.7977***	0.7968***
SQPRDFD	Produced feed* Produced feed	β25	-1.2958***	-1.3917***	-1.3817***
SQACRE	Grazing acres* Grazing acres	β26	0.0343**	0.0438***	0.0431***
PRDACRC	Produced feed* Grazing acres	β27	0.6393***	0.6820***	0.6780***
Inefficiency Model					
Constant	Constant	δ0	0.7550	6.8463**	2.0193**
AGE	Age of manager	δ1	0.0139	0.0178*	0.0053*
SCHED	Years of School	δ2	0.0387	0.1154**	0.0304*
SQYRED	Years of School* Years of School	δ3	-0.0038	-0.0087**	-0.0023**
EXPER	Dairy Experience	δ4	-0.0014	-0.0008	-0.0002
EXNTV	Number of Extension visits	δ5	-0.0130	-0.0130*	-0.0042*
NUMCOW	Number of milk cows	δ6	-0.0449**	-0.0058	-0.0047
RECODS	Dairy Records	δ7	-0.3827*	-0.4116**	-0.1209*
FDSTO	Feed storage	δ8	-0.0949*	-0.4799	-0.0389
H20DS	Distance to water point	δ9	0.0541	-0.0157	-0.0240
CREDIT	Used Credit	δ10	-0.3092	-0.4251*	-0.1611**
OFARM	Off-Farm employment	δ11	0.3308	0.1924	0.0167
WLKMODR	Walking distance to tarmac ratio	δ12	0.6875**	0.6002**	0.1371**
AEZ	Agro-ecological zone	δ13	-1.2774***	-1.2248***	-0.3633***

Table 4.4 (Continued)

Variable Name	Variable Label	Parameters	Original Model	Half-Normal Model	Exponential Model
Variance Parameters					
Lambda	Lambda = σ_u / σ_v	λ	3.5766***	3.6999***	3.8158***
Sigma	Sigma = $\sqrt{(\sigma_v^2 + \sigma_u^2}$	σ^2	0.5681***	1.7922***	0.5622***
Sigma(v)	Sigma(v)	σ_v	0.15297	.46761	.14253
Sigma(u)	Sigma(u)	σ_u	0.54710	1.73013	.54388
Sigma-squared (v)	Sigma-squared (v)	σ_v^2	0.02340	.21866	.02032
Sigma-squared (u)	Sigma-squared (u)	σ_u^2	0.29932	2.99334	.29580
Gamma	Gamma = $\sigma_u^2 / \sigma_v^2 + \sigma_u^2$	γ	0.9275	0.9319	0.9357
Log likelihood	Log likelihood		-61.70612	-389.2387	-62.5111
Cost Efficiency	Cost Efficiency		66.7941%	27.4501%	31.6782%

Source: Source: Sample Survey of Dairy Households in the Marginal zones of Kenya, June-September, 2006.

* Significant at 10% level (p< 0.10)
** Significant at 5% level (p<0.05)
*** Significant at 1% level (p<0.001)

the MLEs coefficients and cost inefficiency of the models are similar to those of the exponential model. The first model is the original model before data adjustments to correct for heteroscedasticity, correlation and orthogonality condition. As pointed out by Aigner, Lovell and Schmidt (1977), the parameter λ (where λ= σu/ σv i.e. the ratio of standard deviations of the error terms), embodies the stochastic frontier model's level of inefficiency under half- normal distribution assumption. As a result, the half-normal frontier model is parameterized in terms of λ and σ2 (the model variance). The estimated values of λ equals 3.5766, 3.6999 and 3.8158 for the half-normal original model, half-normal final model and exponential final models respectively. This indicates that the one-sided error term *(u*) dominates the systematic error *(v)* as shown in Table 4.4 . These lambda estimates are all significant at 0.1 percent level. Another measure of the level of inefficiency in the variance parameters is the Gamma (γ) parameter (where

$\gamma = \sigma_u^2 / \sigma_v^2 + \sigma_u^2$). It is the ration of the errors in equation 4.1 and is bounded between 0 and 1, where if γ =0 inefficiency is not present, and if γ=1 there is no random noise[5]. For the respective translog models in Table 5.3, γ is estimated at 0.9275, 0.9319 and 0.9357. This can be interpreted that over 92 percent of random variation in the models is explained by inefficiency; implying a high level of inefficiencies exist in dairy farming.

4.5. Hypothesis Testing

Generalized log likelihood[6] ratio test was used to test several hypotheses of interest to this analysis. Table 4.5 presents the results of the various null hypotheses tested. First, was a nested hypothesis to determine whether the dairy farmers exhibit a Cobb-Douglas form of technology and whether the specification is an adequate representation of the stochastic cost frontier model? The null hypothesis, H_0: β_{ik}=0 is

Table 4.5: Likelihood Ratio Tests

Hypothesis	Null Hypothesis	Df	Calculated value	p-value	Decision
The Cobb-Douglas specification is an adequate representation of the cost frontier function:	H_0: $\beta_{ik}=0$	21	352.9639	0.0000	Reject H_0
The Inefficiency effects are absent from the model:	H_0: $\gamma = \delta0 = \ldots = \delta13 = 0$	14	86.7586	0.0000	Reject H_0
The inefficiency effects are not stochastic:	H_0: $\gamma = 0$	1	147.6114	0.0001	Reject H_0
The inefficiency effects are not a linear function variables specified:	H_0: $\delta0 = \delta1 = \ldots = \delta13 = 0$	13	71.9974	0.0000	Reject H_0

Source: Source: Sample Survey of Dairy Households in the Marginal zones of Kenya, June-September, 2006.

rejected in favor of the translog production function. The second hypothesis specifies that the inefficiency effects are all together absent from the model i.e. H_0: $\gamma = \delta0 = \ldots = \delta13 = 0$.

5 *If γ is not significantly different from 0, the variance of the inefficiency effects is 0 and the model reduces to a mean response function in which the inefficiency variables enter directly (Battese and Coelli, 1995).*

6 *The idea behind the LR test is simple: If the a priori restrictions are valid, the restricted and unrestricted (log) LF should not be different. Hence log likelihood (λ)=0. But if not the case, the two LFs will diverge. In a large sample, λ follows the chi-square distribution. .We can therefore find out if the divergence is statistically significant, say at 1 or*

This implies that there are no stochastic inefficiencies in the model and consequently the specification of the inefficiency model is redundant. This hypothesis is rejected. The third null hypothesis specifies that the inefficiency effects are not stochastic. It explores the test that each farm is operating on the economically efficient cost frontier and that the non-systematic inefficiency effects are zero i.e. $\gamma = 0$. This hypothesis is rejected in favor of the presence of stochastic inefficiency effects. The fourth final hypothesis considered specifies that the inefficiency effects are not a linear function of the institutional and socioeconomic variables as specified in the model. And that they have no effect on the level of cost inefficiency i.e. $H0: \delta 0 = \delta 1 = \ldots = \delta 13 = 0$. This hypothesis is strongly rejected as well, thus implying that the joint effect of these institutional and socioeconomic variables have a statistically significant effect on the cost inefficiencies.

4.6. Kernel Density

According to Battese and Coelli (1996), estimation of cost inefficiency can only be implemented if the inefficiency effects are stochastic and have a particular distributional specification .The main assumption made is that u is non-negative, and has truncated half normal distribution, $N(0, \sigma_u^2)$. To confirm this assumption, kernel densities function is plotted in Limdep (Green, 2002). Figure 5.1 shows the distribution of the inefficiency measuring variable, u for this study. The results look like the distribution extends to the negative quadrant, thus violating the above assumption. However, the statistics of the kernel density (see Appendix A) indicate that u has a mean of 0.4532, a minimum of 0.0546 and a maximum value of 2.7033. These statistics

5 percent level of significance. Or else, we can find out the p-value of the estimated λ (Gujarati, 2003).

combined with the kernel density function still imply that *u is* non-negative truncated half-normal distribution as assumed in the analysis.

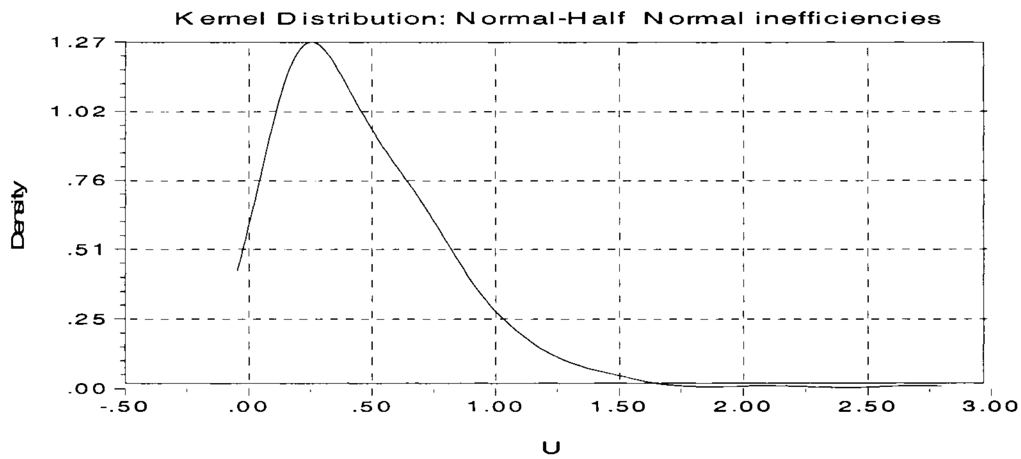


Figure 4.1: kernel Density Distribution for Normal-Half Normal *u* Distribution.

4.7. Economic or Cost Inefficiency

As discussed earlier in Chapter 3 (see equations 3.7 and 3.8), cost inefficiency is calculated as:

$CI_i = \exp(-u_i)*100$ (*CI is converted into a percent by multiplying the equation by 100*).

Cost inefficiency is calculated using conditional expectation of the above equation, conditioned on the composed error e_i (where $e_i = v_i + u_i$) and evaluated using the estimated parameters presented in Table 4.6 from the translog cost function. CI is computed for each farm with the households inefficiency later disaggregated into various institutional and socioeconomic characteristics accounting for the inefficiencies.

Most of the model variables in the stochastic frontier model and the inefficiency model accounting for inefficiencies are statistically significant. The estimate of λ is 3.6999 and σ is 1.7922 and are significantly different from zero, indicating a good fit and

Table 4.6: Maximum Likelihood Estimates of the Translog Cost Frontier and Inefficiency Model

Variable Name	Variable Label	Parameters	Translog Model
Stochastic Frontier Model			
Constant	Constant	β0	6.8806***
LNQNT	Milk output	β1	-0.1692***
LNFDP	Feed price	β2	0.0003
LNHELP	Health price	β3	0.2968***
LNWAGE	Wage	β4	1.2598***
SQQNT	Milk output* milk output	β5	0.0308***
SQFD	Feed price*Feed price	β6	0.0049
SQHEL	Health price *Health price	β7	0.0011
SQWAGE	Wage * Wage	β8	-1.5289***
QNTFDC	Milk output*feed price	β9	0.0095
QNTHELC	Milk output*health price	β10	0.0146
QNTWAGC	Milk output* Wage	β11	0.2569***
FDHELC	Feed price*health price	β12	0.0034
FDWAGC	Feed price *wage	β13	-0.0463*
HELWAGC	Health price*Wage	β14	0.0418*
QNTPRDC	Milk output*Produced feed	β15	-0.0810***
QNTACRC	Milk output* Grazing acres	β16	-0.0606***
FDPRDC	Feed price* produced feed	β17	-0.0005
FDACRE	Feed price* Grazing acres	β18	0.0099
HELPRDC	Health price* produced feed	β19	0.0044
HELACRC	Health price* Grazing acres	β20	-0.0012
WAGPRDC	Wage* produced feed	β21	0.0756*
WAGACRC	Wage* Grazing acres	β22	-0.0810
LNPRDFD	Produced feed	β23	0.7114***
LNACRE	Grazing acres	β24	0.7977***
SQPRDFD	Produced feed* Produced feed	β25	-1.3917***
SQACRE	Grazing acres* Grazing acres	β26	0.0438***
PRDACRC	Produced feed* Grazing acres	β27	0.6820***
Inefficiency Model			
Constant	Constant	δ0	6.8463**
AGE	Age of manager	δ1	0.0178*
SCHED	Years of School	δ2	0.1154**
SQYRED	Years of School* Years of School	δ3	-0.0087**
EXPER	Dairy Experience	δ4	-0.0008
EXNTV	Number of Extension visits	δ5	-0.0130*
NUMCOW	Number of milk cows	δ6	-0.0058
RECODS	Dairy Records	δ7	-0.4116**
FDSTO	Feed storage	δ8	-0.4799
H20DS	Distance to water point	δ9	-0.0157
CREDIT	Used Credit	δ10	-0.4251*
OFARM	Off-Farm employment	δ11	0.1924
WLKMODR	Walking distance to tarmac ratio	δ12	0.6002**
AEZ	Agro-ecological zone	δ13	-1.2248***

Table 4.5 (Continued)

Variable Name	Variable Label	Parameters	Translog Model
Variance Parameters			
Lambda	Lambda = σ_u / σ_v	λ	3.6999***
Sigma	Sigma = $\sqrt{(\sigma_v^2 + \sigma_u^2}$	σ^2	1.7922***
Sigma(v)	Sigma(v)	σ_v	.46761
Sigma(u)	Sigma(u)	σ_u	1.73013
Sigma-squared (v)	Sigma-squared (v)	σ_v^2	.21866
Sigma-squared (u)	Sigma-squared (u)	σ_u^2	2.99334
Gamma	Gamma = $\sigma_u^2 / \sigma_v^2 + \sigma_u^2$	γ	0.9319
Log likelihood	Log likelihood		-389.2387
Cost Efficiency	Cost Efficiency		27.4501%

Source: Source: Sample Survey of Dairy Households in the Marginal zones of Kenya, June-September, 2006.

* Significant at 10% level (p< 0.10)
** Significant at 5% level (p<0.05)
*** Significant at 1% level (p<0.001)

correctness of the specified distribution assumption. λ is the ratio of variance of u (σ_u) to variance of v (σ_v) (i.e. $\lambda = \sigma_u/\sigma_v$ =1.73013/ 0 .46761=3.6999) and is an indication that the one sided error term u dominates the symmetric error v. So, the discrepancy between observed cost and frontier cost is due both to technical and to allocative inefficiencies and not as a result of random variability. The distribution of cost inefficiency (CI) of dairy farms is presented in Figure 4.2. The minimum estimated cost inefficiency is 0.0113 percent, the maximum is 81.1137 percent and the mean is 27.4501 percent with a standard deviation of 20.2635 percent. The observation of wide variation in cost inefficiency is not surprising and is similar to the results from similar studies. For example, Parikh *et al.* (1995) reported mean cost inefficiency of 11.5% with a range of 3.0 percent to 41.5 percent for crop farmers in North-West Frontier Province of Pakistan. Karanja (2002) reported a cost inefficiency range of 1 percent to 66.3 percent for coffee farmers in the central province of Kenya. Despite the wide variation in efficiency in this study, about 51% of the farmers seem to be skewed towards cost inefficiency level of 25 percent and below (Figure 4.2). The implication of these results is that in the short run, there is a scope to reduce dairy production costs by 27 percent perhaps by improving

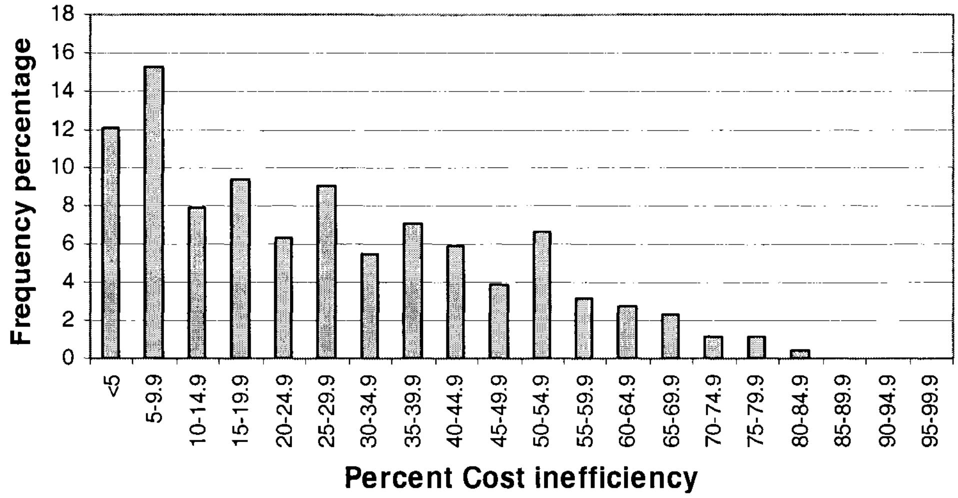


Figure 4.2: Frequency Distribution of Predicted Cost Inefficiency

institutional and socio-economic setups which seem to impact on efficiency. It implies that on average about 27 percent of dairy costs incurred can be avoided without any loss in total output of milk. However, each main breed kept might have different estimated mean cost inefficiency.

Estimation of mean cost reduction given prices and fixed factor endowments reveals that dairy farmers can be better off to the tune of Kshs. 9,057.58 with a range of Kshs. 70.2 to Kshs. 47,285.06; which could be realized by eliminating inefficiencies.

4.7.1 Breed Cost Inefficiency

It can be recalled that the use of exotic breeds and /or upgrading to exotic grades is generally discouraged in the marginal zones because of their perceived higher nutritional demand, low milk yield, poor adaptability and perceived low production performance under smallholder management conditions (Rege, 1998; Kahi *et al.*, 2000; Wakhungu,2000). This argument is investigated by categorizing and exploring the farm specific cost inefficiency of the main breeds kept. Table 4.7 shows that 50 percent of farmers keeping Friesian, 50 percent Ayrshire, 37 percent Guernsey, 33 percent jersey and

Table 4.7: Range of Cost Inefficiency by Breed

Range of CI Percernt	Friesian	Ayrshir e	Guernsey	Jersey	Sahiwal	Boran	Zebu	Zebu cross
<20	50.00	50.00	37.50	33.33	47.83	10.00	14.29	33.33
20-39	25.00	30.77	50.00	50.00	30.43	-	57.14	13.33
40-59	16.89	15.38	-	16.67	13.04	80.00	14.29	46.67
60-79	8.11	3.85	12.50	-	8.70	10.00	14.29	-
80-99	-	-	-	-	-	-	-	6.67
Total	100	100	100	100	100	100	100	100

Source: Source: Sample Survey of Dairy Households in the Marginal zones of Kenya, June-September, 2006.

47 percent Sahiwal operate at or below 20 percent mean cost inefficiency. The large exotic breeds i.e. Friesian and Ayrshire have the largest percentage of farms with the lowest costs, followed by Sahiwal. Over 50 percent of farms with small size exotic breeds i.e.Guernsey and Jersey operate between 20-39 cost inefficiency. The majority of Boran farms operate at 40-59 percent, zebu farms 20-39 percent and zebu crosses operate at 40-59 percent. These results seem to reveal that the large exotic breeds and sahiwal experience lower operational costs than the other breeds.

4.7.2 Estimated Cost Reduction and Profit Increase By Breed and Milk Society

The amount of cost reduction and percent of profit increase for each farm is computed. The results are presented by breed and quintile range of CI in Tables 4.8. The results show that Ayrshire has the lowest cost inefficiency of 24.36 percent followed by Friesians with CI of 25.08 percent, Jersey 25.54 percent and Guernsey 30.17 percent. The

Table 4.8: Mean Cost Reduction and Percent Increase in Profits by Range and Breed

Breed	CI Category	Percent of farms	CI percent	Cost Reduction (Kshs).	Percent Profit increase
Frisian	<20	50.00	8.01	5905.19	40.13
	20-39	25.00	29.74	11430.47	69.63
	40-59	16.89	48.53	13992.43	57.98
	60-79	8.11	67.11	13654.76	92.42
	80-99				
	Overall mean	100.00	25.08	9280.94	56.65
Ayrshire	<20	50.00	10.14	4864.04	10.39
	20-39	30.77	29.35	9421.24	275.17
	40-59	15.38	47.21	13603.61	98.82
	60-79	3.85	77.86	16863.61	25.04
	80-99				
	Overall mean	100.00	24.36	8072.33	143.73
Guernsey	<20	37.50	14.72	5734.78	31.25
	20-39	50.00	33.49	10328.12	79.13
	40-59				
	60-79	12.50	63.25	13201.28	57.80
	80-99				
	Overall mean	100.00	30.17	8964.76	51.64
Jersey	<20	33.33	12.66	4646.77	86.75
	20-39	50.00	27.41	10366.08	101.23
	40-59	16.67	45.69	22763.12	184.81
	60-79				
	80-99				
	Overall mean	100.00	25.54	10525.82	116.59
Sahiwal	<20	47.83	12.71	4244.70	63.04
	20-39	30.43	31.82	7582.19	65.10
	40-59	13.04	50.61	7293.71	71.43
	60-79	8.70	69.77	10262.10	33.88
	80-99				
	Overall mean	100.00	28.43	6181.41	61.48
Boran	<20	10.00	16.35	5139.70	
	20-39				
	40-59	80.00	52.47	13074.88	73.72
	60-79	10.00	66.99	11270.95	53.63
	80-99				
	Overall mean	100.00	50.31	12100.97	74.85
Zebu	<20	14.29	17.41	12898.87	
	20-39	57.14	28.39	4778.96	110.43
	40-59	14.29	59.62	22932.03	76.38
	60-79	14.29	64.58	7492.91	25.41
	80-99				
	Overall mean	100.00	36.46	8919.95	86.62

Table 4.8 (continued)

Breed	CI Category	Percent of farms	CI percent	Cost Reduction (Kshs).	Percent Profit increase
Zebu Cross	<20	33.33	6.11	5221.74	64.46
	20-39	13.33	31.55	6211.02	22.01
	40-59	46.67	50.17	12475.68	61.38
	60-79				
	80-99	6.67	81.11	15999.68	180.87
	Overall mean	100.00	35.06	9457.35	70.01
All Breeds	<20	44.71	9.15	5579.37	40.96
	20-39	27.84	29.74	10199.63	102.49
	40-59	19.61	49.52	13729.87	106.22
	60-79	7.45	67.80	12998.33	70.97
	80-99	0.39	81.11	15999.68	180.87
	Overall mean	100.00	27.45	9057.58	76.72

Source: Source: Sample Survey of Dairy Households in the Marginal Zones of Kenya, June-September, 2006.

indigenous breeds were lead by Sahiwal with 28.43 percent, Zebu upgrades 35.06 percent, Pure Zebu 36.46 percent, and Boran 50.31 percent cost inefficiency. The large exotic breeds predominate in low operational costs. If inefficiencies are addressed, Ayrshire breed keepers would realize a mean profit increase of 143.73 percent followed by Jersey keepers with 116.59 percent. Overall, the analysis shows that there exists unexploited potential of increasing milk profits across all the breeds, through improved efficiency to reduce costs of production. If inefficiencies are addressed, the average current level of profits would increase by 76.72 percent.

Estimated cost reduction and profit pncrease by milk cooperative society and CI range are presented in Table 4.9. The results show that Kilungu and Mbooni Cooperative societies which are in the Agro-Ecological zone Upper Midland (UM) II and UM III have the highest cost inefficiency of 36.34 and 39.14 respectively. This zone has cool and wet climate with an altitude range of 1,800-2,000 masl. It also has relatively high and more reliable rainfall. It is therefore more conducive to exotic dairy cattle and was expected to be

Table 4.9: Mean Cost Reduction and Profit Increase by Milk Cooperatives

Milk Society	CI Category	Percent of farms	CI percent	Cost Reduction (Kshs)	Percent Profit increase
UM- Cooperatives					
Kilungu	<20	24.32	11.71	5567.24	30.65
	20-39	29.73	29.46	11027.12	128.14
	40-59	35.14	49.08	11928.58	244.27
	60-79	10.81	69.29	19243.12	116.19
	80-99				
	Overall mean	100.00	36.34	10903.98	153.45
Kikima	<20	12.20	14.62	4573.20	41.44
	20-39	46.34	30.23	8220.05	146.20
	40-59	24.39	50.64	12788.76	88.31
	60-79	17.07	64.43	10245.34	72.61
	80-99				
	Overall mean	100.00	39.14	9235.41	98.36
Marginal Cooperatives					
Masii	<20	64.71	8.58	5430.18	47.71
	20-39	21.18	29.20	11051.13	126.00
	40-59	10.59	49.98	14477.25	34.45
	60-79	3.53	66.70	12456.17	65.36
	80-99				
	Overall mean	100.00	19.38	7826.40	63.78
Wamunyu	<20	67.31	9.38	6143.68	46.59
	20-39	21.15	29.02	9928.18	69.26
	40-59	7.69	50.94	21770.26	80.72
	60-79	1.92	71.83	11735.72	92.18
	80-99	1.92	81.11	15999.68	180.87
	Overall mean	100.00	19.31	8443.37	62.15
Makueni	<20	25.00	6.44	4938.90	8.53
	20-39	30.00	30.69	11547.00	49.74
	40-59	35.00	48.43	13297.00	69.60
	60-79	10.00	72.00	12293.55	21.80
	80-99				
	Overall mean	100.00	34.96	10582.13	44.50
All Societies	<20	44.71	9.15	5579.37	40.96
	20-39	27.84	29.74	10199.63	102.49
	40-59	19.61	49.52	13729.87	106.22
	60-79	7.45	67.80	12998.33	70.97
	80-99	0.39	81.11	15999.68	180.87
	Overall mean	100.00	27.45	9057.58	76.72

Source: Source: Sample Survey of Dairy Households in the Marginal Zones of Kenya, June-September, 2006.

more efficient in dairy production than drier and hotter Masii, Wamunyu and Makueni Cooperatives Societies which are in transitional zone IV. Wamunyu has the lowest CI of 19.31 percent, followed by Masii with 19.38 percent and Makueni with 34.96 percent. The overall inefficiency for all the farms is 27.45 percent.

If inefficiencies are addressed, the farmers in the respective milk societies would reduce costs by Kshs. 10,903.98 in Kilungu, Kshs. 9,235.41 in Kikima, Kshs.7,826.40 in Masii, Kshs 8,443.37 in Wamunyu and Kshs 10582.13 in Makueni. This would result in profit increase by 153.45 percent in Kilungu, 98.36 percent in Mbooni, 63.78 percent in Masii, 62.15 percent in Wamunyu and 44.50 percent in Makueni respectively. The overall profit increase is expected to be 76.72 percent if the factors causing inefficiencies are addressed.

4.7.3 Grazing Systems and Cost Inefficiency by Range

The mean cost reduction and profit increase by grazing systems are presented in Table 4.10. The results show that field grazing is the most efficient form of grazing with 22.13 percent cost inefficiency. However, very few farmers (i.e. only 7) do field grazing. Most of the farmers do semi-zero grazing and have 26.34 percent cost inefficiency whereas 32 farmers undertake zero grazing and realize 36.11 percent cost inefficiency. If inefficiencies are addressed, field grazing farmers would reduce costs by Kshs. 12314.21 and increase profits by 30.84 percent; semi-zero grazing farms would reduce costs by Kshs. 8887.90 and increase profits by 65.56 percent and zero-grazing farms would reduce costs by Kshs.9895.57 and increase profits by 196.97 percent. As population pressure continues to mount and land resources diminish in the marginal zones, intensification of dairy

Table 4.10: Mean Cost Reduction and Profit Increase by Grazing Systems

Grazing System	CI Category	Frequency of farms	Percent of farms	CI percent	Cost Reduction (Kshs)	Percent Profit increase
Zero grazing	<20	9	28.1	9.75	4451.61	84.31
	20-39	10	31.3	31.83	9906.22	182.52
	40-59	9	28.1	52.43	10765.23	320.35
	60-79	4	12.5	69.41	20161.10	110.87
	80-99					
	Overall mean	32	100	36.11	9895.57	196.97
Semi-Zero Grazing	<20	102	47.2	9.26	5654.73	40.15
	20-39	58	26.9	29.32	9789.65	96.76
	40-59	40	18.5	48.83	14498.02	70.98
	60-79	15	6.9	67.36	11088.26	60.33
	80-99	1	0.5	81.11	15999.68	180.87
	Overall mean	216	100	26.34	8827.90	65.16
Field Grazing	<20	3	42.9	3.76	6400.71	1.63
	20-39	3	42.9	30.85	19103.93	65.63
	40-59	1	14.3	51.03	9685.57	19.71
	60-79					
	80-99					
	Overall mean	7	100	22.13	12314.21	30.84

Source: Source: Sample Survey of Dairy Households in the Marginal Zones of Kenya, June-September, 2006.

production would be realized as more farmers adopt the zero grazing system. However, it seems to be the most constrained by the various factors causing inefficiencies in the marginal zones.

4.7.4 Input Use and Cost Inefficiency By Range and Cooperative Society

Input use in dairy varies across the milk cooperative catchments and the range of cost inefficiency. The results for this analysis are presented in Table 4.11. The most efficient producers (with cost inefficiency of less than 20 percent) use more of purchased inputs than the other categories. For example, the most efficient farmers use 786.97 kilograms of concentrates/cow/year, 810.30 kilograms of hay/cow/year, 21.53 kilograms of mineral salts/cow/year, 1,673.78 kilograms of locally purchased feeds/cow/year and 16.32

Table 4.11: Input use and Cost Inefficiency

CI Range	Milk Society	Cases	Concentrate kgs/cow	Hay kgs/cow/	Mineral salts kgs/cow	Local feeds kgs/cow	Produced feeds kgs /cow	Man-Hours/ cow	Grazing area
<20	Kilungu	10	698.48	198.00	11.57	1883.72	13086.33	1754.89	4.83
	Kikima	9	304.00	1350.00	20.00	4197.00	9629.52	1182.30	0.75
	Masii	5	1050.60	903.18	21.74	1492.47	1771.24	1164.42	8.97
	Wamunyu	55	515.02	724.47	20.36	1873.77	1612.48	1117.20	30.54
	Makueni	35	625.09	105.00	35.44	520.43	3864 91	753.98	25.10
	Total	114	786.97	810.30	21.53	1673.78	3144.11	1161.32	16.32
20-39	Kilungu	11	307.00	-	10.20	2987.59	11702.48	2572.27	1 82
	Kikima	19	45.25	-	16.00	2949.89	7273.80	1839.95	2.41
	Masii	18	245.60	295.00	10.30	545.21	3129.43	1142.13	6.74
	Wamunyu	11	355.13	172.88	17.65	427.55	2178.27	1307 75	10.66
	Makueni	12	262.50	118.13	13.40	476.34	1777.11	1045.33	19.00
	Total	71	264.69	224.96	13.58	1537.24	5190.78	1559.74	7.50
40-59	Kilungu	13	187.86	-	6.50	580.77	6110.13	1703.75	1.04
	Kikima	10	138.00	-	17.55	364.70	13091.70	2056.60	2.60
	Masii	9	243.00	165.00	9.54	580.15	7449.96	1615 35	8.11
	Wamunyu	4	175.75	130.82	7.33	235.80	791.36	736.05	32.75
	Makueni	14	55.67	-	6.74	320.43	2240.67	875.04	22.61
	Total	50	171.83	142.21	9.55	436.95	6238.66	1448.95	11.20
60-79	Kilungu	4	243.33	-	10.00	651.50	8136.00	2065.50	0.94
	Kikima	7	97.00	-	14.14	313.96	15960.45	1422.52	2.63
	Masii	3	113.33	315.00	10.17	63.33	2477.67	1055.67	5.58
	Wamunyu	1	42.00	72.00	4.80	288.80	1232.60	240.00	60.00
	Makueni	4	-	-	6.08	-	1344.92	546.88	3.56
	Total	19	136.36	193.50	10.45	278.03	8332.23	1253.38	5.95
80-99	Kilungu	-	-	-	-	-	-	-	-
	Kikima	-	-	-	-	-	-	-	-
	Masii	-	-	-	-	-	-	-	-
	Wamunyu	1	10	54	3	20	103	2700	4
	Makueni	-	-	-	-	-	-	-	-
	Total	1	10	54	3	20	103	2700	4
Total	Kilungu	37	381.58	198.00	9.19	1620.89	9688.65	2013.51	2.18
	Kikima	42	123.50	1350.00	16.45	1977.23	10404.86	1744.75	2.31
	Masii	92	774.12	732.13	17.59	1073.91	2594.01	1191.65	8.25
	Wamunyu	60	431.18	636.07	18.16	1349.36	1473.88	1213.03	23.76
	Makueni	54	401.26	111.56	15.84	335.96	2147.47	863.08	18.94
	Total	285	528.84	667.82	16.04	1196.21	4345.71	1322.10	11.88

Source: Source: Sample Survey of Dairy Households in the Marginal Zones of Kenya, June-September, 2006.

acres of dairy grazing land. In comparison, the most inefficient farmers in the CI category 60-79 percent use 136.36 kilograms of concentrates/cow/year, 193.50 kilograms of hay/cow/year, 10.45 kilograms of mineral salts/cow/year, 278.03 kilograms of locally purchased feeds/cow/year and 5.95 acres of dairy grazing land. However, they use less of own produced feeds and labour than the inefficient categories. For example, the most efficient farms used 3,144.11 kilograms of produced feed/cow/year and 1,161.32 man-hours of labour whereas the most inefficient category (60-79 percent) used 8,332.23 kilograms of produced feed/cow/year and 1,253.38 man-hours of labour respectively. It seems as if the inefficient farmers use more of farm produced feeds which are usually of lower quality, and very small quantities of market purchased feeds which are relatively of higher quality.

4.7.5 Institutional, Socioeconomic Factors and Cost Inefficiency

This far, the analysis has only focused on the stochastic frontier part of the model. This section turns into the sources accounting for inefficiency estimated in the model. The inefficiency model results are presented in Table 4.12. A negative sign on a parameter means that the variable decreases inefficiency (in other words, it increases efficiency), while a positive sign increases inefficiency (i.e. efficiency decreases). The results are discussed below.

Table 4.12: Institutional, Socioeconomic Factors and Cost Inefficiency

Inefficiency Model			
Variable Label	Variable description	Parameters	Estimates
Constant	Constant	δ0	6.8463**
REHAGE	Age of manager	δ1	0.0178*
EHSCHED	Years of School	δ2	0.1154**
EHSQYRED	Years of School* Years of School	δ3	-0.0087**
REXPER	Dairy Experience	δ4	-0.0008
EHEXNTV	Number of Extension visits	δ5	-0.0130*
EHNUMCOW	Number of milk cows	δ6	-0.0058
EHRECODS	Dairy Records	δ7	-0.4116**
EHFDSTO	Feed storage	δ8	-0.4799
EHH20DS	Distance to water point	δ9	-0.0157
EHCREDIT	Used Credit	δ10	-0.4251*
EHOFARM	Off-Farm employment	δ11	0.1924
EWLKMODR	Walking distance to tarmac ratio	δ12	0.6002**
EHAEZ	Agro-ecological zone	δ13	-1.2248***
Variance Parameters			
Lambda	Lambda = σ_u / σ_v	λ	3.6999***
Sigma	Sigma = $\sqrt{(\sigma_v^2 + \sigma_u^2}$	σ^2	1.7922***
Sigma(v)	Sigma(v)	σ_v	.46761
Sigma(u)	Sigma(u)	σ_u	1.73013
Sigma-squared (v)	Sigma-squared (v)	σ_v^2	.21866
Sigma-squared (u)	Sigma-squared (u)	σ_u^2	2.99334
Gamma	Gamma = $\sigma_u^2 / \sigma_v^2 + \sigma_u^2$	γ	0.9319
Log likelihood	Log likelihood		-389.2387
Cost Efficiency	Cost Efficiency		27.4501%

Source: Source: Sample Survey of Dairy Households in the Marginal zones of Kenya, June-September, 2006.

* Significant at 10% level (p< 0.10)
** Significant at 5% level (p<0.05)
*** Significant at 1% level (p<0.001)

4.7.5.1 Socioeconomic Factors

The results reveal that the age variable of the dairy manager is positive and significantly (p-value is 0.0504) increases inefficiency in smallholder dairy. This implies that as age of manager's increases, inefficiency increases as well. The variable on experience i.e. the number of years of dairying was negative but insignificant. Rahaman

(2004) also reported a study on profit efficiency among Bangladeshi rice farmers where years of rice growing experience had a negative effect on profit inefficiency. A possible explanation of these results is that the age variable picks up the effects of physical strength of the manager whereas years of experience represent the acquired skill in dairy management. As the managers grow older, learning by doing attenuates as their physical strength starts to decline (Liu and Zhung, 2000). These results are also shown in Table 4.13 where the CI category of less than 20 had the youngest farmers with 47 years and also with relatively more years of experience.

Table 4.13 Age, Experience, School Years and Cost Inefficiency

Range of CI Percernt	Age (Years)	Experience (Years)	Schooling (Years)	Number of Cases
<20	47.9518	17.720	8.07	50
20-39	49.6268	16.864	8.73	71
40-59	53.9100	15.189	7.00	114
60-79	54.6842	21.579	8.84	19
80-99	30.0000	8.000	12.00	1
Total	50.0176	16.598	8.23	255

Source: Source: Sample Survey of Dairy Households in the Marginal zones of Kenya, June-September, 2006.

This finding is consistent with a study on cost inefficiency by Parikh *et al.* (1995) for crop farmers in North-West Frontier Province of Pakistan where they found evidence that age had a positive impact on cost inefficiency. Karanja (2002) on the other hand reported a cost inefficiency study for coffee farmers in the central province of Kenya where age had a negative impact on cost inefficiency. However, the difference between these two studies and the current study is that, the age variable is specifically for the dairy manager whereas in these previous studies, the age variable was for the head of the household head who is not necessarily the manager of the enterprises. Also, the age variable lumped together physical strength of the head of the household and experience whereas in the current study, age picks the physical strength only and experience is a separate variable.

The positive sign on years of school variable indicates that an increase in the number of school yeas increase cost inefficiency. This relationship is significant at 5 percent level. The descriptive statistics on Table 4.14 present similar and consistent results with an exception of 40-59 CI range. When years of schooling are squared, the quadratic structure of age is negative and significant at 5 percent level, implying that farm cost inefficiency decreases with an increase in the number of school years of the dairy manager. The dairy managers with an average of 7 years of schooling are in CI range 40-59, whereas those with an average of 8 years of school are in CI 0-20. As inefficiency increase, the average number of years of schooling increase. Hence an effort to emphasise full primary schooling seems to reduce cost inefficiency in dairy production. This reveals that a level of education equivalent to primary school with 8 years is sufficient for dairy farmers to make informed choices and improve cost inefficiency.

The analysis seems to indicate that farmers with school years below 8 are cost inefficient and those with more than 8 are also inefficient. This could probably be explained by the fact that high education (university and college) attenuates the desire for farming. Instead, farmers probably concentrate on salaried employment. This finding is consistent with results from other economic efficiency studies. For example, Karanja (2002) reported a cost inefficiency study for coffee farmers in the central province of Kenya where the number of school years had a positive effect on cost inefficiency. Rahaman, 2004 also reported a study on profit efficiency among Bangladeshi rice farmers where education years had a positive effect on profit inefficiency. However, Parikh *et al.*

(1995) reported a study on crop farmers in North-West Frontier Province of Pakistan where they found evidence that education had a negative impact on cost inefficiency and was significant at 10 percent level. From this analysis, it can be concluded that a dairy farmer in the marginal zones does not need education beyond primary school (i.e 8 years) to be able to make informed choices about general dairy management. However, less than 8 years of primary education or more seems to result in cost inefficiency.

The positive coefficient of the off-farm employment of the dairy managers indicates that farmers engaged in off-farm employment activities tend to exhibit higher levels of inefficiency. However, this coefficient was not significant. Also, an interaction between off-farm employment and education variables is positive indicating that educated farmers that have off-farm employment tend to exhibit high cost inefficiency (but the coefficient was insignificant). The allocation of more time to off-farm work produces extra income for the family and eases the pressure from seeking credit, but it has a negative impact on farm activities. Other researchers who made similar findings are : Ali and Flinn (1989); Parikh *et al.* (1995), Karanja (2002) and Rahman (2003).

Three of the socioeconomic factors i.e. number of milk cows, keeping of dairy records and feed storage are farm characteristics. Table 4.11 shows the descriptive statistics of these variables. The number of dairy cows kept variable in the inefficiency model is negative which implies that the variable tends to reduce inefficiency. Thus as the number of cows increase, cost inefficiency decreases. However, this relationship is not statistically significant probably because the heard size of the milking cows is not yet optimal. The most efficient farmers have approximately 4 cows (see Table 4.14). This finding is consistent with a study on cost inefficiency for coffee farmers in the central

Table 4.14: Number of Milking Cows, Farm records and Feed Storage

Range of CI Percernt	Number of Milking Cows	Frequency Percent Keeping Farm Records		Frequency Percent of Feed storage		Percent Number of Cases
		Yes	No	Yes	No	
<20	3.6228	22.35	22.35	41.96	2.75	44.71
20-39	2.3662	7.45	20.39	24.71	3.14	27.84
40-59	2.4400	6.27	13.33	16.86	2.75	19.61
60-79	1.9474	3.92	3.53	6.67	0.78	7.45
80-99	1.0000	0.00	0.39	0.39	0.00	0.39
Total	2.9059	40.00	60.00	90.59	9.41	100

Source: Source: Sample Survey of Dairy Households in the Marginal zones of Kenya, June-September, 2006.

province of Kenya reported by Karanja (2002),where the number of dairy cows kept variable had a negative sign but not statistically significant. Keeping of farm records reduces cost inefficiency. This variable is statistically significant at 5 percent. Table 4.13 shows that as the percentage of farmers who keep records increases, inefficiency decreases. However, only forty percent of the dairy managers keep farm records. Keeping records of activities enables the farmer to make decisions based on the actual realities of the farm which enhances the efficiency of dairy management. Of the studies reviewed so far, no one study on economic efficiency has incorporated keeping of records as a tool for reducing inefficiency in farm operations. Keeping of farm records can be used as one of the policy tools incorporated in extension, to help the farmers improve on the efficiency of dairy operations in the marginal zones.

A negative sign on the feed storage variable indicates that feed storage on farms increases cost efficiency. This variable is not statistically significant. Nevertheless, the most efficient farms have the highest frequency percent of farms who store feeds. Overall about 90.56 percent of dairy farms store feeds.

4.7.5.2 Institutional Factors

The institutional factors considered in this study are credit, distance to water point, extension visits, infrastructure and the Agro-ecological zone i.e. transitional zone IV. The coefficient of the credit use variable is negative and significant at 10 percent level. It therefore implies that credit use significantly reduces inefficiency. The descriptive statistics on Table 4.15 indicate that the most efficient categories have the highest percent of farmers using credit and the most inefficient categories have the lowest percent of farmers using credit. Overall, 53.73 percent of the farms used credit.

Table 4.15: Institutional Factors Influencing Cost Inefficiency

Range of CI Percernt	Frequent percent of Credit Use		Water point distance (kilometers)	Extension visits	Infrastructure Index
	Yes	No			
<20	30.98	13.73	.4746	5.3947	.4927
20-39	12.94	14.90	.4754	2.1831	.4665
40-59	6.27	13.33	.5440	2.1800	.5271
60-79	0.36	3.92	.5263	1.7368	.5523
80-99	0.00	0.39	.4000	.0000	1.0000
Total	53.73	46.27	.4920	3.5765	.5207

Source: Source: Sample Survey of Dairy Households in the Marginal zones of Kenya, June-September, 2006.

This finding is consistent with a study by Karanja (2002) on Coffee farmers in Kenya where the credit variable had a negative significant effect on cost inefficiency at 5 percent level. Other studies consistent with this finding include: Parikh *et al.* (1995) in North-West Frontier Province of Pakistan and Ali and Flinn (1989) in Pakistan.

The coefficient on the distance to the water point variable is unexpectedly negative and is statistically insignificant. Table 4.15 shows that the most efficient farms have the shortest distance to the point of watering dairy cows. And as this distance increases, inefficiency increases. However, the farmers in CI 80-99 are an exception.

Overall 48.1 percent of the farmers have water on their farms.

The negative sign on the number of extension visits variable indicates that an increase in the number of visits decreases cost inefficiency; this relationship is significant at 10 percent level. The result implies that extension increases efficiency of dairy operations. This finding is contrary to a study by Karanja (2002) where it was found that the extension variable had a positive and insignificant effect on cost inefficiencies of Coffee farmers in the Central Province of Kenya. But it is consistent with a study by Parikh *et al.* (1995) in North-West Frontier Province of Pakistan where they found that extension visits had a negative and significant effect on the cost inefficiencies of crop farmers at 5 percent level. Rahman (2003) reports similar findings on Bangladeshi rice farmers although the results were not significant. The descriptive statistics on Table 4.15 indicate that the most efficient farmers had an average of 5 visits per year whereas the most inefficient farmers were not visited by the livestock extension staff at all. Thus, a high frequency of extension visit advice seems to reduce costs of production.

The road infrastructure index variable was positive and significant at 5 percent level. This variable is a ratio between the portions of the walking distance from the homestead to the tarmac road in relation to the whole distance from the homestead to the tarmac road. If the homestead is situated next to the tarmac road, the ratio is 0. And if the household walks the whole distance to the tarmac road, the ratio is 1. This result therefore implies that as the portion of walking distance from the homestead to the tarmac road increases cost inefficiency of dairy operations in the marginal zones with an exception of CI 20-39 category. Table 4.15 indicates that the most efficient farmers walk less than 50 percent of the distance to the tarmac road. Also, as the walking distance to the tarmac road increases, cost inefficiency increases. On average, dairy farmers walk 52 percent of the distance from the homestead to the tarmac road.

The walking distance to the tarmac road seems to pose drudgery to the operations of dairy activities in the marginal zones. The farmers walk relatively long distances to the tarmac when delivering milk to the cooperatives. The dairy inputs from the market have to be carried manually for the whole walking distance to the homestead. Also, the livestock health officers and extension workers walk relatively long distances carrying their treatment kit manually when conducting their routine treatment rounds for animals among households. The speed of undertaking these activities is slowed down by the status of the road infrastructure. The road infrastructure is one of the institutional factors which might require some public action in an effort to expand dairy production in the marginal zones.

Finally, the coefficient on the dummy variable for the Agro-Ecological Zone is negative and statistically significant at one percent level. This suggests that dairy farmers in the lowland marginal zones are less inefficient and closer to their minimum cost frontier than the dairy farmers in the cool and wet hilly pouches of Mbooni and Kilungu areas. This result seems contrary to expectations because exotic dairy cattle usually perform better in the cool and wet hilly regions with relatively high rainfall. Nevertheless, this finding is an indication that lowland marginal zones reduce cost inefficiencies of exotic dairy cows and performs better than in the cool and wet hilly regions.

4.7.6 Marginal Effects

The estimated parameters on the variables of the inefficiency model presented in

Table 4.12 tell us little about the magnitude of the effect of changes on cost inefficiency. The signs on the coefficients merely indicate the direction of the effects that the variables have on inefficiency levels where a negative [positive] coefficient estimate shows that a variable reduces [increases] cost inefficiency. To address this shortcoming, derivation of the marginal effects of the inefficiency variables on cost inefficiency is done through partial differentiation of cost inefficiency with respect to each inefficiency variable.

Frame and Coelli (2001) show that for the i-th firm in the t-th time period, cost efficiency is predicted using the conditional expectation:

$$CE_{it} = E[\exp(-u_{it}) \setminus E_{it} = e_{it}$$

$$= \{\exp(\mu_* + 0.5\sigma_*^2)\}\{\Phi[(\mu_* / \sigma_*) + \sigma_*]\}/\{\Phi(\mu_* / \sigma_*)\}$$

$$= A(B/C) = AD \tag{4.1}$$

where

$\mu_* = (1-\gamma)z_{it}\delta + \gamma e_{it}$,

$\sigma_*^2 = \gamma(1-\gamma)\sigma_s^2$,

$\sigma_s^2 = \sigma_u^2 + \sigma_v^2, \gamma = \sigma_u^2 / \sigma_s^2$, $e_i = v_i - u_i$ and Φ represents the distribution of the standard normal random variable. The marginal effects associated with the thirteen *z*-variables are listed in Table 4.16, evaluated at their sample means. They result from the partial differentiation of equation 4.1 with respect to each of the inefficiency variable. The derived expression for this marginal effect is presented in Appendix B. The results of marginal effects in Table 4.16 show the amount by which cost inefficiency increases if the variable is increased by one unit. For example one year of age increase would increase cost inefficiency by 0.0053 (i.e. 0.53 percent), which results in increase in

Table 4.16: Marginal Effects of the Inefficiency Variables

Variable Label	Parameter	Coefficient	Marginal effects	Percent change in CI	Change in cost (Kshs)	Percent profit change
Age of manager	δ_1	0.0178*	0.0053	0.5269	47.7244	(0.4042)
Years of School	δ_2	0.1154**	0.0342	3.4157	309.3799	(2.6204)
Years of School* Years of School	δ_3	-0.0087**	-0.0023	-0.2253	(20.4067)	0.1728
Dairy Experience	δ_4	-0.0008	-0.0002	-0.0237	(2.1466)	0.0182
Number of Extension visits	δ_5	-0.0130*	-0.0038	-0.3816	(34.5637)	0.2928
Number of milk cows	δ_6	-0.0058	-0.0017	-0.1717	(15.5519)	0.1317
Dairy Records	δ_7	-0.4116**	-0.1182	-11.8186	1070.4795	9.0668
Feed storage	δ_8	-0.4799	-0.1420	-14.2045	(1286.5843)	10.8972
Distance to water point	δ_9	-0.0157	-0.0046	-0.4647	42.0906	(0.3565)
Used Credit	δ_{10}	-0.4251*	-0.1258	-12.5826	(1139.6794)	9.6530
Off-Farm employment	δ_{11}	0.1924	0.0569	5.6948	515.8112	(4.3689)
Walking distance to tarmac ratio	δ_{12}	0.6002**	0.1777	17.7651	1609.0886	(13.6288)
Agro-ecological zone	δ_{13}	-1.2248***	-0.3076	-30.7581	(2785.9403)	23.5966

Source: Source: Sample Survey of Dairy Households in the Marginal zones of Kenya, June-September, 2006.

(.) means the figure is negative

average cost by Kshs 47.72 and a reduction in profits by 0.4042 percent. The coefficient estimates for the constructed dummy variables represent, a one-off shift in cost inefficiency rather than a true marginal effect. For example, farmers who keep dairy records are have cost inefficiency which is 11.82 percent lower than those who do not. By keeping records, farmers reduce average costs by Kshs. 1070 which enhances profits by 9.07 percent, *Ceteris Paribus*. Farmers keeping feed storage have cost inefficiency 14.2045 percent lower than the average. This translates into Kshs 1287 reduced costs and a 10.89 percent profit increase. Use of credit leads to reduction in costs by Kshs. 1140 and increased profit by 9.65 percent. A 1 percent increase in the ratio of walking distance from homestead to the tarmac road results in 18 percent increase in average cost inefficiency and leads to increased costs of Kshs. 1606 and a reduction of profits by

13.62 percent. Finally, farmers in the lowland marginal areas are 30 percent less cost inefficient compared to farmers in the cool and wet hilly zones. This is equivalent to a reduction of costs by Kshs. 2786 and an increase in profit by 23.59 percent.

4.7.7 Conclusions and Recommendations

4.7.7.1 Conclusions

This chapter set out to provide estimates of cost inefficiency in dairy production and to explain variations in inefficiencies among farms through institutional and socioeconomic factors in the marginal zones. Farm specific cost inefficiencies are computed using a cross-sectional survey data collected for the period July 2005 to June 2006. A stochastic frontier model is adopted, and is implemented by using Limdep (Green, 2002). Different functional forms including translog, Cobb-Douglas and quadratic functions were considered. Also, three models based on half-normal, exponential and truncated –normal distributions of the error terms are estimated.

The results showed that results from different functional forms were different. The average cost inefficiencies from different functional forms were 27.4501% for translog model and 12.0452% for Cobb-Douglas model. The quadratic model had no measurable inefficiencies. Although slightly different, this conclusion agrees with Thiam, *et al.*, (2001) in the Meta analysis of technical efficiency in developing countries. They concluded that the Cobb-Douglas production function generally generates lower technical efficiency implying that a more restrictive functional form leads to lower average TE. The results from models assuming different distributions of the error term were also different. The half-normal distribution model gave cost inefficiency of 27.4501% whereas both truncated and exponential distribution models had similar results of 31.6782%. This analysis was carried out using the half-normal distribution assumption that has become the standard choice of most researchers. Therefore, there is a 27% scope for reducing costs of production in dairy. However, CI ranges between 0.01 to 81.11 percent.

The analysis showed that exotic breeds are the most efficient. Ayrshire breed achieved the lowest cost inefficiency of 24.36 percent, Friesians 25.08 percent, Jersey 25.54 percent and Guernsey 30.17 percent. The indigenous breeds were lead by Sahiwal with 28.43 percent, Zebu upgrades 35.06 percent, Pure Zebu 36.46 percent, and Boran 50.31 percent cost inefficiency. If inefficiencies are addressed, Ayrshire would lead by realizing 143.73 percent increase in profits, followed by Jersey with 116.59 percent. And the lowest would be Gurensey with 51.64 percent.

In terms of the cooperative societies, the results showed that those in the transitional zone IV were most efficient. Wamunyu has the lowest cost inefficiency of 19.31 percent, followed by Masii with 19.38 percent and Makueni with 34.96 percent. The upper midland zone cooperatives were not as efficient as expected; Kilungu has 36.34 percent followed by Mbooni with 39.14 respectively. The overall inefficiency for all the farms is 27.45 percent. If inefficiencies are addressed, it would result in profit increase by 153.45 percent in Kilungu, 98.36 percent in Mbooni, 63.78 percent in Masii, 62.15 percent in Wamunyu and 44.50 percent in Makueni respectively. The overall profit increase is expected to be 76.72. Analysis of grazing systems showed that zero grazing is the least efficient with 36.11 percent cost inefficiency. Semi-zero grazing realized 26.34 cost inefficiency and field grazing was the most efficient with 22.13 percent cost inefficiency. As population pressure continues to mount and land resources diminish in the marginal zones, intensification of dairy production would be realized as more farmers adopt the zero grazing system. However, it is the most constrained by the various factors causing inefficiencies. If the identified inefficiencies are eased, zero grazing farms would reduce costs by Kshs.9895.57 and increase profits by 196.97 percent.

One of the marked differences in determining inter-farm differences in cost inefficiency is input use. From this study, the most efficient farmers use 786.97 kilograms of concentrates/cow/year, 810.30 kilograms of hay/cow/year, 21.53 kilograms of mineral salts/cow/year, 1673.78 kilograms of locally purchased feeds/cow/year and 16.32 acres of dairy grazing land. In comparison, the most inefficient farmers in the CI category 60-79 percent use 136.36 kilograms of concentrates/cow/year, 193.50 kilograms of hay/cow/year, 10.45 kilograms of mineral salts/cow/year, 278.03 kilograms of locally purchased feeds/cow/year and 5.95 acres of dairy grazing land. However, the most efficient farms use less of own produced feeds and labour than the inefficient categories. For example, the most efficient farms used 3144.11 kilograms of produced feed/cow/year and 1161.32 man-hours of labour whereas the most inefficient category (60-79 percent) used 8332.23 kilograms of produced feed/cow/year and 1253.38 man-hours of labour respectively. It seems as if the inefficient farmers rely more on farm produced feeds which are usually of lower quality and use market purchased feeds which are relatively of higher quality as supplements or complements.

The impacts of socioeconomic and institutional factors on cost inefficiency were evaluated and their associated marginal effects estimated. Results showed that older farmers, education above eight years of primary school and longer walking distances to the tarmac road are associated with high cost inefficiency whereas the number of

Extension visits, keeping of dairy records, use of credit and lowland transitional marginal zone are associated with low cost inefficiency.

Finally, calculation of the marginal effects has shown that use of dairy records reduce average cost inefficiency by 11.82 percent leading to an increase of profits by 9.1 percent, storage of feeds reduces average cost inefficiency by 14 percent leading to profit increase by 10.89 percent, use of credit reduces cost inefficiency by 12.58 percent leading to profit increase by 9.65 percent, increase of walking ratio distance to the tarmac road increases cost inefficiency by 17.76 percent leading to a reduction of profits by 13.63 percent. Finally farmers in the lower marginal transitional zone reduce average costs by 30.75 percent leading to increased profits by 23.59 percent.

4.7.7.2 Recommendations and Policy Implications

It can be recalled that the main purpose of this study is to enhance economic performance measured through efficiency, production structure and supply response of smallholder dairy farms in the marginal zones of Kenya. One of the most important avenues for increasing efficiency is to address the institutional and socioeconomic setups which cause drudgery in dairy operations. This ultimately helps farmers to reduce production costs and increase milk yield by increasing technical efficiency. This study has concluded that by increasing input use and improving the identified socioeconomic and institutional factors would impact cost inefficiency in the marginal zones. The conclusions reached by this analysis have led us to identify a number of policy issues that are recommended for attention.

1) Road infrastructure:

   The results of this study indicate that infrastructure is one of the factors influencing costs significantly. The distance walked from the homestead to the tarmac road causes drudgery to dairy operations. If the ratio of walking distance to the tarmac road increases by 1 percent costs of production increase by 17 percent resulting in profit decrease by 13.62 percent. The 17 percent increase is the upper bound value. Some farmers might be using low cost or free labour. This finding underscores the importance of providing adequate road net work i.e. feeder roads, weather roads and tarmac roads to reduce the drudgery of transportation from the homestead to the tarmac road in the rural marginal zones. Inadequate and/or poor road infrastructure discourages new investments and significantly increases production costs and lowers the profitability of dairy farms and business.

The rural marginal areas suffer from inadequate physical infrastructure and hampers growth in the rural economy. Poor infrastructure hinders rural development because it impacts agricultural productivity negatively. In addition, the existing roads in the marginal areas are impassable, especially during the rainy season. As a result, the productivity potential in these areas remains untapped. Often, a loss of produce is usually incurred due to wastage in the farms and deterioration of quality of the produce during transportation to the market. Furthermore, poor road network increases transportation costs for inputs and the produce thereby reducing the margins to farmers. Road infrastructure is a public good. New investments and improvements of the existing road net work would therefore require the enhancement of public expenditure on rural infrastructure. This therefore implies that the government remains the main player in rural road development in order to promote smallholder agriculture in the marginal zones. Usually, transportation and the road infrastructure are a system. So, a regional analysis would also be necessary to investigate the type of the required road net work, the business activities in the region and the population of the people affected by transportation and the rural road infrastructure.

2) Extension Services:

In this study the number of extension visits significantly reduces cost inefficiency. It is therefore prudent that farmers have access to extension services. Before the liberalization of the dairy industry in 1993, the extension service agents used to train and visit farmers on their farms. However, after liberalization, extension visits are from farmer to the government extension office i.e. farmers in demand of extension services have to seek for the services from the extension office before they can be attended to. Extension service has a high public good component. The markets for breeding services and animal treatment are barely established in the marginal zones. The cooperative societies and private practitioners who offer these services are quite limited in terms of personnel and equipment. Nevertheless, farmers still rely on them for their survival in dairy production. For example, there are five AI personnel (one in each milk cooperative) and 10 private animal health practitioners (with a certificate or a diploma in animal health), and one with a Bachelor of Veterinary Medicine (BVM), offering animal health services to 891 active farmers-without counting the dormant ones and the rest of livestock farmers. However, dairy farmers are heavily dependent on public extension services in the marginal zones because there is virtually no private sector participation unlike in animal health. Therefore, improvement of extension services, dairy technology development and dissemination as well as other dairy support services that have a high "public good components" will require the enhancement of public expenditure. Indeed, there is a strong case for using public expenditure as a lever to stimulate agricultural development particularly where markets do not exist, even in a liberalized economic environment. Perhaps a strategy of joint extension service provision between the government and the cooperative societies can ameliorate this situation. In the short run, the government can post some of its dairy extension staff and veterinary doctors to the milk cooperative societies on secondment like in the tea sub-sector. However, in the long run the cooperative societies can employ extension staff and veterinary doctors as part of their human resource establishment. The costs of such services would not be explicitly charged but implicitly deducted from the payments to the producers. This would ultimately ensure that the milk cooperative societies take charge of private provision of extension services to their members. However, they should establish the capacity and develop the required financial foundation for these future challenges.

(3) Dairy Records:

Extension services teach farmers the best practices of dairy production. Keeping dairy records is part of the extension service work. In this study keeping records significantly reduced cost inefficiency. The marginal effects showed that keeping records reduces average cost inefficiency by 11.82 percent leading to a reduction of costs by Kshs. 1,070.48 and an increase in profits by 9.07 percent. It is therefore important that farmers are taught on how to keep dairy records and how to analyse, interpret and use the information for decision making to enhance production efficiency. However, one cannot be sure that investments in any variables in the inefficiency model will really improve profits: perhaps good managers keep records. However, good records do not necessarily make good managers.

4) Credit and Rural Financial Markets in the Marginal Zones:

This study has shown that use of credit to purchase dairy feeds and enhance dairy operations reduces cost inefficiency. The marginal reduction of the average cost inefficiency is 12.58 percent which reduces costs by Kshs 1139.67 and increases profits by 9.65 percent. It thus shifts the cost frontier closer to the potential minimum. Credit is necessary to encourage technical innovations, such as purchase of milk yield-enhancing inputs, which cost slightly more, but shifts the production and finally transforms the entire input-output relationships. However, smallholder farmers are risk averse because of uncertainty in repayment and in high interest rates. The main deterrent to borrowing credit by farmers is high interest rates as the annual rate ranges between 12 to 65 percent for commercial banks and village banks, respectively (Kodhek, 2004). In this study 48.1 percent of the farmers (i.e. 137 farmers) did not use credit in the period July 2005 to June 2006. Two of the cooperatives i.e. Wamunyu and Masii offer farmers feed credit and the debt are recovered from the monthly milk deliveries. Coincidentally, it is only in these two cooperatives where farmers have the lowest cost inefficiency. The rest of the cooperatives i.e. Kilungu, Mbooni and Makueni have no facility currently for feed credit. Kilungu and Makueni cooperatives used to have a feed credit facility for farmers, but it collapsed. This finding implies that if farmers are offered affordable credit, efficiency of production would increase.

In the early 1960s, the private commercial banks were required by law to disburse 17 percent of loans to agriculture (Kodhek, 2004). Currently, agricultural lending by commercial banks stands at 5.35 percent of the total lending portfolio. There is a need, therefore, to put in place discretionary policy measures aimed at improving smallholder farmers' access to credit at affordable rates in order to boost dairy productivity and efficiency in the marginal zones. Such policy measures should focus on creating a conducive policy environment for a vibrant rural financial markets and micro-financial institutions that are interlinked with the evolving milk output markets. Now that there are operating milk cooperatives, farmer driven institutions such as credit cooperatives can play a crucial role in this respect. Currently, some of the cooperative societies give feed credit to the farmers based on their milk deliveries. However, there is a need to create appropriate legal and institutional infrastructure to enable dairy farmers to access finance through the use of warehouse receipts and other commodity based collateral.

5) Education and school years:

In this study, education increases cost inefficiency. The results indicate that the most efficient farmers (i.e. the best quintile of <20) have an average of 8.07 years of primary education. As inefficiency increase, the average number of years of schooling increase. The range of cost inefficiency 40-59 has an average of 7 years of primary education. Hence an effort to emphasise full primary schooling seems to reduce cost inefficiency in dairy production. However, education policy is not susceptible to change in the short run. The Kenyan Government has continued to support free primary education policy and is currently planning to introduce a free secondary education policy in the rural areas. However, the benefits of education are realized in the long run. In the short run therefore, the government should focus on dairy production education on the best practices. Non-formal agricultural education, often provided by both public and private extension services, is needed for training of dairy managers, dairy families and workers. Due to absence of markets and institutions in rural areas, the government must be willing to invest in human capital and social infrastructure, for capacity building in a wide range of rural organizations and groups, so as to meet the challenges of agricultural production and food security in the 21st century.

Currently, Land O Lakes promotes dairy industry in Kenya through four avenues: i) enhancing dairy productivity activities through delivery of effective training and services to the smallholder farmers; ii) dairy product quality, safety and affordability activities by improving processors and informal marketers' ability to deliver higher-quality, safe, affordable, and nutritious products to the marketplace; iii) consumer promotion and marketing activities to increase demand for quality dairy products through intensive and focused promotional campaigns to expand domestic and export markets; and, iv) dairy industry capacity building activities to create sustainable local capacity of business, cooperatives and industry groups to improve services and enhance demands and supply for inputs, market information, policy reform and industry. The work of Land O Lakes should be extended to the marginal zones as well for the benefit of the smallholder dairy farmers. In the agricultural sector, formal and informal education is essential for improving food security and rural employment and reduction of poverty. Formally and informally educated farmers are better placed to receive information on extension, research, entrepreneurship and commerce, and apply it in productive activities.

CHAPTER V

PRODUCTION STRUCTURE OF SMALLHOLDER DAIRY FARMS

5.1. Introduction

In this chapter, the production structure of the smallholder dairy farms in the marginal zones is determined using duality theory in production and costs. A restricted translog cost function is estimated simultaneously with the dairy input demand cost share equations in a systems approach using the Iterative Zellner method. The objective of this analysis is to determine the different impacts that exogenous variables have within and across dairy input demands. The price elasticities of factor demands are computed as well as the Morishima elasticity of substitution among pairs of inputs. Finally, the scale elasticity of dairy production is computed and discussed.

5.2. Data, variable definition and computation

The variables used to analyse production structure are created from the survey data described in Chapter 3, Section 3.5. The dependent variable is the natural logarithm of the normalized total variable costs (LNCOST) of milk production for the period July 2005 to June 2006. The normalized total variable cost is a sum of expenditures on concentrates, mineral salts, milking serve, hay, locally purchased feeds (i.e. Napier grass, maize stover and other grasses), tick control, cattle treatment, labour and imputed expenditure on own produced feeds divided by labour wage rate. The independent variables are calculated as indicated below.

Milk quantity (Q): This is the total annual milk production (litres) produced in the period under study. It is a sum of monthly milk production for one year for each household.

Price of protein feeds: This is a natural logarithm of the proxy for protein feeds price. Protein feeds constitute concentrates, mineral salts and milking salve. They are dairy inputs purchased from formal markets. To get the price for each, the annual expenditure is divided by the respective annual quantity purchased. The prices are summed up to get the price of one bundle of protein feeds consisting of one kilogram of concentrates, one kilogram of mineral salts and one kilogram of milking serve. This price is normalized by the labour wage rate to get a proxy for protein feeds price. Then, the natural logarithm of this proxy is the variable for price of protein feeds.

Price of roughage feeds: This is a natural logarithm of the proxy for roughage feeds price. Roughage feeds are hay and locally purchased feeds (i.e.Napier grass, maize stover and grasses). The price for each feed is obtained by dividing annual expenditure with the respective annual quantity purchased. The prices are summed up to get the price of a bundle of roughage feeds consisting of one kilogram of hay and one kilogram of locally purchased feeds. It is then normalized by the labour wage rate to get a proxy for roughage feeds prices. The natural logarithm of this proxy is the variable for price of roughage feeds.

Price of animal treatment: Price of animal treatment is a natural logarithm of the normalized average price of animal treatment per year. The price of animal treatment is obtained by dividing annual treatment expenditure with the respective number of treatments per year. This price is normalized by the labour wage rate and a natural logarithm is computed as the variable for animal health treatment price.

Price of tick administration: Price of tick administration is a natural logarithm of the normalized average price of tick administration per year. The price of tick administration is obtained by dividing annual tick expenditures with the respective number of tick administrations per year. This price is normalized by the labour wage rate and a natural logarithm is computed as the variable for price of tick administration.

Price of own produced feed: Price of own produced feeds is a natural logarithm of the imputed normalized price of producing own feeds per year. Imputed expenditure on own produced feeds is simply how much it would cost the farmer if the feeds produced on the farm were to be purchased from the local markets within the neighbourhood. To obtain the imputed price, imputed expenditures are divided by the estimated weight of own produced feeds. This price is then normalized by the labour wage rate and a natural logarithm is computed as the variable for price of own produced feed.

Labour wage rate: The wage rate is the price of labour per man-hour in each household. It is obtained by dividing annual expenditures on labour with the annual number of man-hours worked per household. The wage rate variable is used to normalize total variable cost and all the independent price variables.

Area for grazing: Area for dairy grazing is the only fixed input. It is entered as a natural logarithm of the area for dairy grazing.

Input shares: The input shares are calculated by dividing the respective input expenditures by the total variable costs. The descriptive statistics of the created variables used in this analysis are shown in Table 5.1 below.

The average annual total variable cost is Kshs. 8,1385.81. The average annual milk output is 4,027.672 litres per household. A bundle of one kilogram of concentrate, mineral salts and milking serve on average costs Kshs. 419.5397. The protein feeds bundle is the most expensive of all the other feeds. The cheapest feed input is the own produced feed with an average of Kshs. 2.4016. The average wage rate is Kshs. 7.7010. Labour input has

Table 5.1: Descriptive statistics of production structure variables

	Measuring units	Mean	Std. Deviation	Coefficient of variation(%)
Total variable cost	Kenyan Shillings (Kshs.)	81385.81	129527.2	134.5778
Annual milk production per farm	Litres	4027.672	6079.603	126.1176
Protein feed price	Kshs./bundle of 3 kgs	419.5397	235.1678	56.0538
Roughage feed price	Kshs./bundle of 2kgs	10.3564	9.2502	89.3187
Treatment price	Kshs./Case treated	224.2733	328.2663	146.3688
Tick price	Kshs/administration	294.2185	393.0733	133.5991
Wage rate	Kshs./Man-hour	7.7010	2.7996	36.3537
Produced feed price	Kshs./kg	2.4016	1.1055	46.0318
Input shares				
Protein feed share	Ratio	0.1585	0.1478	93.2492
Roughage feed share	Ratio	0.2225	0.1720	77.3034
Treatment share	Ratio	0.0359	0.0398	110.8635
Tick share	Ratio	0.0335	0.0299	89.2537
Labour share	Ratio	0.3620	0.1944	53.7017
Produced feed share	Ratio	0.2522	0.1873	74.2665

Source: Source: Sample Survey of Dairy Households in the Marginal zones of Kenya, June-September, 2006.

the largest share of 0.3620 (i.e. 36.2 percent) of all input expenditures. Tick control and Animal treatment expenditure shares are the lowest with approximately 3 percent of total expenditure. In comparison to all the other feeds, the protein feeds have the lowest share of expenditure (i.e. 15.85 percent).

5.3. Systems Model Results

The cost function model consisting of equations 3.14 and 3.15 in Chapter 3, Section 3.3.1 with cross equation restrictions of homogeneity in input prices, symmetry and adding up property is estimated using cross-sectional data for the period July 2005 to June 2006. The restriction of linear homogeneity in the input prices is imposed by normalizing cost and the other prices by the labour wage rate (Green 2002). In the estimation of the model, the cost share equation for labour is deleted to sustain linear independence of the remaining equations. The estimated parameters of the system and the associated asymptotic z-values are reported in Table 5.2. Most of the coefficients of the model are statistically significant

Table 5.2: Estimated Coefficients of the Translog Cost Function

Variable description	Parameters	Parameter	Standard Error	|b/St.Er.|	P[|Z|>z] |
Constant	α_0	-38.318488	36.0233	-3.8400	0.0001
Milk output	α_Q	3.717104	8.6980	0.4270	0.6691
Protein feeds price	α_P	-0.030767	0.0115	-2.6740	0.0075
Roughage feeds Price	α_R	0.755854	0.0553	13.6720	0.0000
Treatment price	α_H	0.039231	0.0098	3.9880	0.0001
Tick price	α_T	0.582107	0.0278	20.9730	0.0000
Produced feed price	α_O	0.139173	0.0190	7.3140	0.0000
Output*Output	β_{QQ}	3.730359	1.0845	3.4400	0.0006
Protein price*protein price	β_{PP}	0.000161	0.0000	5.5900	0.0000
Roughage price*Roughage price	β_{RR}	0.078409	0.0067	11.7890	0.0000
Treatment price*Treatment price	β_{HH}	0.000032	0.0000	3.0310	0.0024
Tick price*Tick price	β_{TT}	0.000828	0.0001	15.3470	0.0000
Produced feed price*produced feed price	β_{OO}	0.000082	0.0001	1.1760	0.2396
Output*Protein price	β_{QP}	0.025507	0.0019	13.3690	0.0000
Output*Roughage feeds Price	β_{QR}	-0.071647	0.0067	-10.6610	0.0000
Output*Treatment price	β_{QT}	-0.000261	0.0013	-0.2070	0.8358
Output*Tick price	β_{QT}	-0.069282	0.0035	-19.8640	0.0000
Output*Produced feed price	β_{QO}	0.012132	0.0029	4.1550	0.0000
Protein Price*Roughage feeds Price	β_{PR}	0.000058	0.0000	1.2470	0.2124
Protein Price*Treatment price	β_{PH}	0.000002	0.0000	0.2000	0.8414
Protein Price*Tick price	β_{PT}	-0.000007	0.0000	-0.3350	0.7377
Protein Price*Produced feed price	β_{PO}	-0.000052	0.0000	-1.5930	0.1111
Roughage feeds Price*Treatment price	β_{RH}	-0.000099	0.0000	-1.9770	0.0481
Roughage feeds Price*Tick price	β_{RT}	0.001674	0.0001	11.3490	0.0000
Roughage feeds Price*Produced feed price	β_{RO}	-0.000544	0.0001	-6.2980	0.0000
Treatment price*Tick price	β_{HT}	-0.000052	0.0000	-2.9780	0.0029
Treatment price*Produced feed price	β_{HO}	0.000022	0.0000	1.4300	0.1526
Tick price*Produced feed price	β_{TO}	-0.000266	0.0000	-7.8360	0.0000
Output*Acres	β_{OA}	-0.100364	0.1139	-0.8810	0.3782
Protein feeds Price*Acres	β_{PA}	0.000059	0.0000	2.1330	0.0329
Roughage feeds Price*Acres	β_{RA}	0.000058	0.0000	1.3580	0.1745
Treatment price*Acres	β_{HA}	0.000003	0.0000	0.3820	0.7026
Tick price*Acres	β_{TA}	0.000044	0.0000	2.2900	0.0220
Produced feed price*Acres	β_{OA}	-0.000071	0.0000	-1.8310	0.0671
Dairy acres	β_A	-1.160007	0.5610	-2.0680	0.0387
Dairy acres*Dairy acres	β_{AA}	1.238200	0.6218	1.9910	0.0465

Source: Source: Sample Survey of Dairy Households in the Marginal zones of Kenya, June-September, 2006.

and have the expected signs except the coefficient for protein feeds which has a negative sign.

A well behaved cost function is concave in the input prices, and its input demand functions are strictly positive. However, the translog cost function does not satisfy these restrictions globally (Berndt and Wood, 1975). The positivity condition is satisfied if the fitted cost shares of all the inputs are positive; this was checked and found to be true for each household with an exception of a few in roughage and tick demand functions. The concavity condition is satisfied if the Hessian matrix of the second order partial derivatives is symmetric and negative semi-definite (Varian, 1992). The Hessian is symmetric by assumption (Kant and Nautiyal, 1997). The concavity condition is satisfied if the Hessian matrix of the second order partial derivatives is symmetric and negative semi-definite (Varian, 1992). The Hessian is symmetric by assumption (Kant and Nautiyal, 1997). The parameter estimates of the input share demand equations are equal to those in the cost function-input demand system due to simultaneity. These parameters have little economic meaning of their own (Binswanger, 1974). But, they are best evaluated by the values which they imply for elasticities of substitution and elaticities of factor demand discussed later.

5.4. Hypothesis Testing

Generalized log likelihood ratio test is used to test several hypotheses related to the system of dairy production structure in this analysis. Table 5.3 presents the results of the three null hypotheses tested. The first hypothesis attempts to establish whether the translog cost function is a simultaneous system with the input demands in the production structure. The hypothesis tested is of the cross equation restrictions in the share equations by estimating them as a system without the cost equation. The null hypothesis is that there is no difference between estimating the input demand system with cross equations restrictions and estimating the translog cost/input demand system of equations simultaneously. The null hypothesis is rejected in favor of the translog cost/input demand

Table 5.3: Likelihood Ratio Tests

Null hypothesis	Restricted log likelihood	Unrestricted log likelihood	Computed Statistic	No. of restrictions	Critical table value	p-value	Decision
Estimation of input demand system with cross equation equality restrictions is not different from estimation of the translog-demand system:	123.5652	1606.2051	2965.2798	1	3.8414	0.0000	Reject H_0
Estimation of input demand system without cross equation equality restrictions is not different from estimation of the translog-demand system:	123.5652	1641.182	3036.5111	41	19.6751	0.0000	Reject H_0
Estimation of input demand system with and without cross equation equality symmetry restrictions is not different:	1606.2051	1641.8208	71.2313	20	18.307	0.0000	Reject H_0

Source: Source: Sample Survey of Dairy Households in the Marginal zones of Kenya, June-September, 2006.

equations as a simultaneous system of production structure.

The second hypothesis specifies that estimating the input demand system of equations without the cross equation restrictions is not different from estimating the translog cost/input demand system. This implies that there is no need of imposing cross equations restrictions and symmetry in the input demand equations. This hypothesis is rejected. The third null hypothesis specifies that estimating the input demand system of equations without cross equation equality symmetry restrictions is not different from estimating the input demand system of equations with cross equation equality symmetry restrictions. This hypothesis is also rejected in favor of imposing symmetry in the input demand system of equations. These results imply that imposing symmetry and cross equation equality restrictions in the input demand system and estimating them simultaneously with the translog cost function is an economically true representation of the production structure of dairy in the marginal zones. It is observed that very large gains in estimation efficiency of the system follow when the cross equation restrictions are imposed. Thus, milk supply, costs and input demands are an integrated simultaneous system of activities in dairy production.

5.5. Input Demand Price Elasticities

As earlier mentioned, the parameters of input demand shares have little economic meaning of their own (Binswanger, 1974). However, they are used to determine variable elasticities of substitution and factor demand of the inputs. The price elasticites are a function of the input share parameter estimates and the input share variables themselves as shown in Chapter 3 equations 3.16 to 3.17. The results of price elasticities for dairy input demands are shown in Table 5.4. The parameters estimates of own price elasticities

Table 5.4: Estimated Price Elasticities of the Translog Cost Function

Input Items:	Protein feeds demand	Roughage feeds demand	Demand for animal treatment	Demand for Tick Administration	Labour demand	Own produced feeds demand
Protein feed price	**-2.328412***** **(0.023576)**	2.502541 (3.599495)	-2.111929 (7.704242)	-4.285899 (4.859472)	-4.318605 (18.898211)	2.850351 (8.870101)
Roughage feed price	-2.593648 (3.395439)	**-1.151118***** **(0.615729)**	-2.523465 (5.45141)	-1.585368 (8.416966)	-3.807824 (10.19960)	0.151054 (5.104626)
Animal treatment price	-4.041275 (7.580561)	-0.494424 (9.071102)	**-1.765213 ***** **(0.642758)**	3.189816*** (0.011132)	-8.595361 (5.619736)	-3.081924*** (0.009220)
Tick administration price	-3.760632*** (0.0100265)	-1.202651*** (0.0097723)	3.253751 *** (0.011118)	**-2.208417***** **(0.0209993)**	-8.278418*** (0.798226)	-4.084581*** (0.044306)
Wage rate	-6.071546 (14.576002)	-1.323139 (7.496768)	-1.956414 (4.589133)	-2.851511 (4.589143)	**-2.275161***** **(7.334627)**	-4.525273 (5.735175)
Price of own feeds	-3.507752*** (0.048182)	0.706697** (0.311899)	-3.426819*** (0.534294)	-3.472315*** (0.011132)	-4.071378*** (0.0403235)	**-1.714289***** **(0.005386)**

Source: Source: Sample Survey of Dairy Households in the Marginal zones of Kenya, June-September, 2006.
*** Significance at 1 percent level
** Significance at 5 percent level

of all the six inputs are negative, as they must be in keeping with the *a priori* theoretical expectations. The t-values of the coefficient estimates are put in parentheses. These elasticities are statistically significant at 1 percent level. The own price elasticities are elastic, ranging from -2.328412 for protein feed to -1.151118 for roughage feeds. The results imply that increasing prices of any of the dairy inputs by 1 percent would result in reduction of input use by more than 1 percent. For example for a 1 percent increase in respective input prices, farmers reduce protein feeds per cow by 10.27 kilograms, roughage feeds is reduced by 16.54 kilograms per cow, labor is reduced by 36.38 man-hours per cow per year and own produced feeds is reduced by 59.66 kilograms per cow per year. Similar observations are made for tick and animal treatment if prices increase. These results imply that with input market liberalization, farmers are now quite responsive to price changes. Protein feeds i.e. concentrates, mineral salts and milking serve have the highest response to a 1 per cent change in price of the inputs.

The cross price elasticity of all the input demands with respect to protein feed price are negative except for roughage feeds and own produced feeds. This means that protein feeds and the other inputs except roughage feeds and own produced feeds are complements. On the other hand, protein feeds-roughage feeds and protein feed-own produced feeds are substitutes. However, all the coefficients are insignificant meaning that a price change of protein feeds usually has no impact on the use of the other animal feeds on the farm. These results seem to be plausible because usually, protein feeds are purchased in small quantities and mixed with prepared Napier grass (either purchased roughage or own produced) and fed to the cows when milking. Therefore, if price of protein feeds go up by 1 per cent, there is no significant change in demand for the other dairy inputs most of which are produced on farm.

The cross price elasticity of the input demands with respect to roughage feed price is negative for protein feed, animal treatment, tick control and labor demand. Thus, they are complements. Usually, roughage feed once purchased in the neighborhoods requires labor to gather, collect and store on the farms. Also, due to high incidences of ticks in the marginal areas, roughage feeds which are usually grasses or maize stover collected and fed tend to have ticks. This increases the incidences of ticks on dairy cows as well as the related animal sicknesses. Therefore, the demand for tick control and animal treatment increases. However, roughage and own produced feeds are substitutes. But, the coefficient is insignificant.

The cross price elasticity of input demands with respect to treatment price is negative except for tick control. This implies that animal treatment complements all the other dairy inputs in production. However, the results indicate that animal treatment and tick control are significant substitutes. This is an unexpected result and the only possible explanation to this occurrence is that when the price of animal treatment increases, management of tick control is intensified. This safeguards the cows from conducting diseases which are mostly brought about by ticks e.g. east cost fever. Thus, farmers concentrate more in tick disease prevention as health costs increase. Hence they are substitutes. The cross-price elasticities of input demands with respect to tick control price are all negative except for animal treatment. Thus tick control and the other inputs are complements, but a substitute of treatment as explained previously. The price elasticities of input demands with respect to labour are negative and insignificant for all the cases.

Thus, labor and the other inputs are insignificant complements.

Own produced feed and roughage feeds are substitutes. Both of them are roughages but from different sources: own produced feeds are produced on the farm whereas roughage feeds are purchased from informal markets. The elasticity coefficient is significant at 5 per cent level. On the other hand own produced feeds and the other dairy inputs are complements. Own produced feeds particularly Napier grass and concentrates are mixed and fed to cows when milking. The greater the demand for own produced feeds, the higher the demand for labor. The demand for own produced feeds and the health of dairy cows also go together.

5.6. Elasticity of Dairy Input Substitution

The elasticities of substitution vary with input share levels. Hence, they are calculated at the mean level of input shares. In this study, the the Morishima elasticities of substitution are computed and discussed. These results are presented in Table 5.5. The Morishima elasticity of substitution measures the percentage change in the ratio of a pair of factors with respect to a change in the ratio of their respective prices. It can be observed that the Morishima elasticities are asymmetric. Most of the variable price input elasticity coefficients are negative. Hence they are Morishima complements. However, protein feed-roughage feed, protein feed-own produced feed, roughage feed-own produced feeds and animal treatment-tick control are Morishima substitutes. In the current dairy production structure, all the Morishima Elasticity coefficients are elastic. The results seem to indicate that if the price of protein feeds goes up, farmers result in purchasing roughage feeds (mostly Napier grass which is usually used when milking) and using own feeds. Thus, a 1 percent change in the ratio of roughage-protein feed prices, the roughage-protein quantity

Table 5.5: Morishima Elasticities of Substitution between Inputs

Input Demand for:	Protein Feeds	Roughage Feeds	Animal Treatment	Tick Administration	Labour	Own produced feeds
Protein price	0.000000	3.653660	-2.416174	-4.144257	-2.043444	4.564641
		(3.403474)	(5.997019)	(9.76605)	(2.171492)	(12.08077)
Roughage price	-2.627246	0.000000	-2.827709	-1.443726	-1.532663	1.208730
	(4.2869678)		(9.0245)	(6.45409)	(8.546130)	(2.22717)
Animal treatment price	-3.744766	-1.697811	0.000000	3.331458	-6.320201	-1.367634
	(7.584213)	(9.99510)		(6.45409)	(6.580149)	(3.729386)
Tick administration price	-2.897893	-2.406037	-3.491221	0.000000	-6.003257	-2.370291
	(9.669783)	(3.403474)	(4.085834)		(7.456149)	(3.729386)
Wage rate	-2.452006	-0.496689	-3.731063	-7.347838	0.000000	-2.810983
	(2.35619)	(9.99510)	(4.085834)	(8.45409)		(3.735649)
Own feeds price	-3.374905	-5.85186	-2.306262	-2.709868	-1.796217	0.000000
	(8.252961)	(5.38439)	(4.093386)	(4.607802)	(6.342800)	

Source: Source: Sample Survey of Dairy Households in the Marginal zones of Kenya, June-September, 2006.

ratio responds by 3.65 percent. If the price change results from increase of protein prices, then more roughage substitute's protein feed. Thus, if price of protein feeds increases, the change in percentage ratio of the inputs leads to more roughage and own produced feed in the feed mix. The Morishima elasticity coefficients seem to augiment the price elasticity coefficients where a 1 percent increase in price of protein feeds results in 2.50 percent increase in roughage feeds and 2.85 percent increase in own produced feeds. However, a 1 percent increase in price of roughage and own produced feeds results in decrease of protein feeds by -2.59 percent and -3.51 percent respectively. These values indicate that in the existing dairy technology it is easier for roughage feeds and own produced feed to substitute protein feeds out of production. On the other hand, protein feeds seem to be purchased to complement roughage feeds and own produced feeds. This result seems to be logical in the light of the current production structure which is based on own produced feeds and informal market feed sources with relatively less formal market feed dependence.

The results of the production structure of dairy in Kenya are seemingly different from a study on farm level feed demand in Turkey (Fuller *et al.*, 1999) although the production and animal feeding technologies are different in the two countries as well as the feed types. In the marginal zones of Kenya, the own-price elasticities are quite elastic whereas in Turkey the feed prices are inelastic. In Kenya, farmers mostly depend on own produced feeds or purchase roughage feeds from informal markets with relatively small amounts of protein feeds purchased from the formal input markets. The protein feed price therefore is relatively elastic. However, in Turkey, farmers depend on formal feed markets for their dairy production. Therefore, the own-price elasticity of formula feeds demand is the most inelastic for dairy producers. This is not surprising because formula feeds contain the highest levels and the greatest balance of protein and energy (Fuller *et al.*, 1999). Turkish dairy producers rely on formula feeds to provide a substantial portion of the animal's daily nutritional requirements, supplementing formula feeds with less expensive grain, oilseed meals, and by-product feeds. Forages account for 55 percent of dairy cattle rations and protein formula feeds 45 percent. Thus, dairy producers in Turkey feed significantly more protein feeds than Kenyan farmers. The price elasticities for dairy inputs are inelastic. The Morishima elasticities of substitution indicate that formula feed is easily substituted by forage, by-product meal and grain. But, it is harder for formula feed to substitute forage, by-product meal and grain. On the other hand, protein feeds are purchased mostly to complement roughage feeds and own produced feeds and not as a substitute in Kenya.

5.7 Scale Economies in Dairy Production

Economies of scale are usually defined in terms of the relative increase in output resulting from a proportional increase in all inputs. A natural way to express the extent of scale economies is as the proportional increase in cost resulting from a small proportional increase in the level of output, or the elasticity of total cost with respect to output (Christense and Green, 1976). Christensen and Green (1976) defines scale economies (SCE) as unity minus this elasticity:

$$\text{SCE}= 1 - \partial \ln C / \partial \ln Y \qquad (5.1)$$

where C is the total variable cost and Y is the output. In the estimated translog cost function/input demand systems in Table 5.2, the coefficient of milk out (α_o) is 3.717104 (i.e. $\partial \ln C / \partial \ln Y$ =3.717104). Therefore, the scale economies (SCE) is -2.717104 (i.e. 1-3.717104=-2.717104). The SCE is negative and hence implies scale diseconomies in dairy production. These scale economies measure the relative changes in output when expenses change but input prices are held constant. This is a reciprocal of the cost elasticity with respect to output. Therefore, the scale economy for milk production in the marginal zones is 0.269 (i.e.1/3.717104). The existing literature does not have similar reports of studies in livestock which can be used to compare this finding. But in other sectors of economy particularly in the developed countries, studies indicate scale economies of 2.4 in forestry logging in Canada (Kant and Nautiyal, 1997) and 0.79 in a study on import demand for the United States (Yanikkaya, 2004). The scale economy factor of 0.269 means that every 1 percent increase in milk output would lead to an increase in variable costs by 0.269 percent since milk production is experiencing scale diseconomies.

5.8 Conclusions and Recommendations

5.8.1 Conclusions

The purpose for this chapter has been to determine the existing structure of dairy production in the marginal zones using the translog approximation to the cost function.

Neoclassical duality results were extensively used for this purpose. In the view of the liberalized market structure for dairy sector in Kenya, this is quite appropriate. The analyses uses cross-sectional survey data collected for the period July 2005 to June 2006. The translog cost function was estimated jointly with the dairy input demand equations by using Zellner's (1962) systems analysis of seemingly unrelated regression method which provides asymptotically more efficient estimates than the production function estimates given by the principle of ordinary least squares. This method is implemented by using Limdep (Green, 2002). Various hypotheses are tested to establish whether the dairy production structure attests to the assumptions of restrictions across the translog cost function and the system of input demands according to theoretical underpinnings.

The hypotheses of the cross equation restrictions in the share equations is tested by estimating them as a system without the cost equation, and with and without the cross equations equality restrictions. A likelihood ratio test is used to test the hypotheses. Without the assumption of restrictions, the share equations have no theoretical basis (Green, 2002). The results showed that the symmetry restrictions cannot be rejected. It also emerges that cross equation equality restrictions in the input demand system and estimating them simultaneously with the translog cost function is an economically true representation of the production structure of dairy in the marginal zones. It is observed that very large gains in estimation efficiency of the system follow when the cross equation restrictions are imposed. It is therefore concluded that the cost of production and input demands are an integrated simultaneous system of activities in dairy production.

A primary interest for this study is the estimation of price elasticities of factor demands and the elasticities of substitution between inputs. The results show that all feed price elasticities are elastic. Protein feeds-Roughage feeds, protein feeds-own produced feed, roughage feed-own produced feed and animal treatment-tick control are substitutes. All the other inputs are complements. The uptake of protein feeds versus roughages and own produced feeds is of central importance in this analysis. The results show that a 1 percent increase in price of protein feeds results in 2.50 percent increase in roughage feeds and 2.85 percent increase in own produced feeds. However, a 1 percent increase in price of roughage and own produced feeds results in decrease of protein feeds by -2.59 percent and -3.51 percent respectively. Therefore, farmers find it easier to substitute protein feeds which are of high quality, with roughage feeds and own produced feed which are usually of poor quality. It is also observed that farmers purchase protein feeds as significant complements for roughage and own produced feeds. This finding leads to the conclusion that with rising prices of protein feeds, the dairy farmers would have a greater tendency to purchase less protein feeds and to use more roughage feeds and own produced feeds which are of poor quality. In addition, farmers seem to purchase small quantities of protein feeds just to complement roughage and own produced feeds.

The results of scale economies show that dairy production experiences scale diseconomies. It is further established that the scale economy factor is 0.269 which implies that every 1 percent increase in milk output would lead to an increase in variable costs by 0.269 percent since dairy production is experiencing scale diseconomies in the marginal zones. It is therefore concluded that one of the hindrances of expanding dairy production in the marginal zones is the seemingly low uptake of protein feeds and the increasing costs of production.

5.8.2 Recommendations and Policy Implications

It can be recalled that one of the main goals of this study is to determine the production structure of smallholder dairy farms in the marginal zones of Kenya. The uptake of protein feeds and the way farmers combine them with the other dairy inputs influences technical efficiency in dairy production. The results of this chapter and the previous one has lead to the conclusion that adjusting input combinations to allow more uptake of protein feeds and improving the identified institutional and socioeconomic setups would impact on the high cost of production realized and ameliorate the scale diseconomies in dairy production. The conclusions reached by this analysis have led us to identify a number of policy issues that are recommended for attention.

1) Protein feeds and markets:

This study has shown that there is a very low uptake of protein feeds compared to roughage feeds and own produced feeds. It has also shown that a bundle of protein feeds is more expensive than any of the other feed types used in dairy production. The price of a bundle of protein feeds is Kshs 419.54, Kshs. 10.36 for a bundle of roughage feeds, Kshs. 2.40 for own produced feeds and Kshs. 7.70 per man-hour for labour. A bundle of protein feeds consists of 1 kilogram of concentrates with an average price of Kshs. 14.85, 1 kilogram of mineral salts with a price of Kshs. 67.89 and 1 kilogram of milking serve with a price of Kshs 379.86. Thus the price of concentrates is still hire than the price per unit of the other dairy feeds. The average quantities of the feeds fed per cow per year are: 423.53 kilograms of concentrates, 1,436.32 kilograms of roughage, 667.82 kilogram of hay and 2870 kilograms of own produced feeds. Primary statistics shows that 63 percent of farmers used concentrates, 85 percent used milking serve and approximately 86 percent used mineral salts. On the other hand 75 percent of farmers used roughage and 98 percent used own produced feeds. These results indicate that the protein feeds are the most expensive of all the feeds. They are also used by relatively few farmers, particularly the concentrates, compared to the other feeds, and they have the least quantities used in production.

Concentrates contain the highest levels and the greatest balance of protein and energy feed for dairy cows. Yet on average, a cow is given 1.16 kilograms of concentrates per day (i.e. 423.53/365). The high prices of protein feeds seem to militate against their substantial use in dairy production. This result then leads to substitution of protein feeds by roughage feeds or relatively small quantities used to complement own produced feeds. This finding seems to imply that there is need to rationalize the animal feeds markets as well as the quality of animal feeds and remove the constraints which result in high prices of animal feeds. The goal would be to make animal feeds fordable to farmers. There is therefore need to study and determine the efficiency of animal feeds markets in Kenya. The findings can come up with results shedding some light on the operations of animal feeds markets and prices. This would determine the kind of possible policies which can be used to intervene in the industry in order to enhance its operations and ultimately influence the expansion of the dairy sector.

2) Production of protein feeds and matching protein needs to roughage consumption:

In the marginal zones, there is relatively little research work done on dairy feeds and especially protein feed production and matching the various nutrient requirements for the dairy cows. There is therefore need for extension and research on matching protein needs with the current roughage consumption. Production scientists believe that this one action could double production all by itself (Bill Wailes- a personal communication). On the farm level, it might be necessary to create two simultaneous extension programs to teach farmers on how to grow high protein feeds suitable to the marginal zones, and to encourage dairy producers to use high protein feeds respectively.

3) Scale diseconomies in dairy production:

The results of scale economies show that dairy production experiences scale diseconomies. Thus, dairy farmers are facing increasing costs of production. If the milk output increases by 1 percent, variable costs increase by 0.269 percent. As discussed in the previous chapter, any errors in production decisions translate into higher costs for the producer. Also, according to the findings of Chapter 4, constraints in some of the institutional and socioeconomic factors result in high cost inefficiencies which translate into increased costs of production. Thus, the results of the two analytical approaches seem to be in agreement.

In order to ameliorate the current situation of increasing costs of production facing farmers, there is need for interventions in areas where there are imperfect markets, information asymmetries and where the necessary production inputs are in form of public goods as seen in Chapter 4. Therefore, improvements in farm gate terms of trade and supply response requires the enhancement of public expenditure on rural road infrastructure, water supply, extension education, credit services , farm record keeping services as well as other agricultural support services that are not provided in the market place. The policy interventions should focus in creating institutional and socionomic frameworks necessary for reducing drudgery, transaction and production costs, and increasing access to production resources and markets by smallholder farmers in the marginal areas.

CHAPTER VI

SUPPLY RESPONSE OF SMALLHOLDER DAIRY FARMS

6.1. Introduction

Kenya's stated policy is to increase dairy (milk) production through sustained liberalization of output and input markets (RoK, 1994). At the same time there is a continuing ambiguity about the precise role of public policy in a liberalized market environment. This is encapsulated in the potential clash between the traditional income support before the liberalization period and the output expansion goals during the market liberalization era, and the encouragement of sustainable production technologies on the other hand. This clash is most significant in those situations where the former goals might be associated with interventions to increase intensity of production activities and increased use of chemical and mechanical inputs, while the latter would seek a withdraw of government involvement, and instead encourages private sector participation. The tension between these non-coincident goals is particularly important in the current circumstances of the Kenya's liberalized agricultural and livestock sectors. In this scenario, there is need to explore how government policy might best be focused to achieve output expansion goals. Byerlee *et al.*, (1993) and Ali (1995) suggest that realizing future productivity gains after structural adjustments in developing countries might require significant adjustments in the institutions serving agriculture.

This chapter addresses some of the issues that need to be confronted in determining what adjustments might be appropriate for rural areas. The chapter presents supply response analysis results of smallholder dairy farms in the marginal zones. Following the theoretical framework presented in Chapter 3, Section 3.4, supply response analysis is based on the profit function approach. A restricted translog profit function is estimated simultaneously with the dairy input demand profit share equations using the Iterative Zellner method. Studies on supply response have mainly used the systems analysis to estimate the profit function simultaneously with the accompanying input demand systems. The parameters derived from the estimations are then used to compute price and non-price elasticities which are usually market price, institutional and socio-economic responses by farmers. These elasticities are computed in this study and their policy implications discussed.

6.2. Data, variable definition and computation

The variables used for supply response analysis are derived from the survey data described in Chapter 3 Section 3.6. The dependent variable is the natural logarithm of the normalized restricted profit (LNPF) of milk production for the period July 2005 to June 2006. The normalized restricted profit is the difference between annual total milk revenue and total variable cost (i.e. sum of expenditures on concentrates, mineral salts, milking serve, hay, locally purchased feeds, tick control, cattle treatment, labour and imputed expenditure on own produced feeds) divided by weighted milk price per litre. The independent variables are calculated as indicated below.

Price of protein feeds: This is a natural logarithm of the proxy for protein feeds price. Protein feeds constitute concentrates, mineral salts and milking salve. They are dairy inputs purchased from formal markets. To get the price for each feed item, the feed expenditure is divided by the respective annual quantity purchased. The resulting prices per unit are normalized by dividing them with the price of milk per litre respectively. The normalized prices are then summed up to get a proxy for protein feed price of one bundle of protein feeds consisting of one kilogram of concentrates, one kilogram of mineral salts and one kilogram of milking serve. The natural logarithm of this proxy is the variable for price of protein feeds.

Price of roughage feeds: This is a natural logarithm of the proxy for roughage feeds price. Roughage feeds are hay and locally purchased feeds (i.e.Napier grass, maize stover and grasses) combined with own roughage feeds produced on the farm. The price for each feed is obtained by dividing annual expenditure or imputed expenditure with the respective annual quantity purchased/produced . The respective prices are normalized by dividing them with the price of milk per litre. They are then summed up to get a proxy for roughage feed price for a bundle of roughage feeds consisting of one kilogram of hay, one kilogram of locally purchased feeds and one kilogram of own produced feeds. The natural logarithm of this proxy is the variable for price of roughage feeds.

Price of tick administration: Price of tick administration is a natural logarithm of the normalized average price of tick administration per year. The price of tick administration is obtained by dividing annual tick expenditures with the respective number of tick administrations per year. This price is normalized by the price of milk per litre and a natural logarithm is computed as the variable for price of tick administration.

Price of animal treatment: Price of animal treatment is a natural logarithm of the normalized average price of animal treatment per year. The price of animal treatment is obtained by dividing annual treatment expenditures with the respective number of treatments per year. This price is normalized by the price of milk per litre and a natural logarithm for it is computed as the variable for animal health treatment price.

Labour wage rate: The wage rate is the price of labour per man-hour in each household. It is obtained by dividing annual expenditures on labour with the annual number of man-hours worked per household. The wage rate is then divided by the price of milk per litre to normalize it and a natural logarithm is computed as the variable for labour wage.

Weighted milk price: Milk from the farm has several outlets through which it is sold. They include: cooperative delivery, neighbours, milk hawkers (raw milk traders) and hotels/kiosks/schools. Each outlet has a different price from the others. To compute a proxy for milk price representing all the outlets, the amount sold through each outlet is divided by the total milk produced and multiplied by the respective outlet price. The weighted milk price is then the sum of the weighted outlet prices. The weighted milk price is used to normalize variable input prices. All the normalized input prices are expected to impact normalized restricted profits negatively.

Institutional and socio-economic factors: A number of institutional and socio-economic variables were defined as short run fixed factors in the profit function model. In line with other studies (e.g. Sidhu and Baanante, 1981; Farooq *et al.*, 1991), where the area under paddy constrains production in the short run, the area of grazing is assumed to constrain dairy expansion in the current study. The acreage variable is defined as the natural logarithm of the area reserved for grazing dairy cattle. The number of years of schooling is expected to influence supply response of smallholder farms. This variable is represented by the natural logarithm of the number of school years of the dairy manager. The provision of extension services has been the monopoly of government mainly through the ministry in charge of agriculture, and the Ministry of Livestock Development and Fisheries. Due to lack of donor funds for extension services, and following the reduction of government allocation in agriculture after the liberalization of the dairy sub-sector, extension services have become increasingly unavailable to farmers particularly in the marginal areas. Therefore, the number of extension visits variable for the survey period July 2005 to June 2006 is expected to constrain dairy expansion. The ratio of the walking distance from the household to the tarmac road is a drudgery which is expected to slow down dairy operations. The walking ration variable is represented by the natural logarithm of the ration of the walking distance to the tarmac road. Water scarcity and the distance to the watering point for the dairy cattle is another area of concern in the expansion of dairy production. The variable is represented by the natural logarithm of the distance to the water point and can generate another piece of information for the policy makers seeking the expansion of dairy production through water supply in the rural areas. Finally, the number of dairy cows kept is expected to influence milk output supply, profits, labour employment and demand for dairy feeds. This variable is represented by the natural logarithm of the number of milk cows. The descriptive statistics of the variables included in supply response analysis are shown in Table 6.1.

Input shares: The input shares are calculated by dividing the respective normalized input expenditures by the restricted normalized profit. Primary statistics of the shares of variable inputs and output in dairy production for the sample farms are presented on Table 6.2.

The descriptive statistics of the variables included in the estimation of profit function show that the coefficients of variation for milk output price is 14.7643 percent. Input prices show a greater variation than the output price, ranging between 35.0962 percent for labour wage and 160.8700 percent for tick control. This suggests that there is sufficient variation across farms to permit statistically significant parameters to be

Table 6.1: Descriptive statistics of variables for supply response analysis of sample farms

Variable Description	Units	Mean	Standard deviation	Coefficient of variation (%)
Weighted milk price	Kshs./litre	20.0699	2.9632	14.7643
Normalized restricted profit	Kshs./farm	2369.5209	3374.2961	142.4042
Normalized protein feed price	Kshs /3 kgs	19.1096	12.3447	64.5996
Normalized roughage feed price	Kshs /2 kgs	0.9347	1.2728	136.1735
Normalized tick administration price	Kshs/administration	0.9462	1.5222	160.8700
Normalized treatment price	Kshs/treatment	10.2482	14.0326	136.9269
Normalized wage rate	Kshs/Man-hour	0.3815	0.1339	35.0962
Grazing area	Acres	9.5452	12.7707	133.7919
Years of schooling	Number	7.8433	4.3733	55.7584
Number of extension visits	Number	2.8034	3.1765	113.3088
Walking distance ratio to tarmac road	Ratio	0.6490	0.3876	59.7263
Number of cows	Number	3.4627	4.0106	115.8239
Water distance (km)	Kilometers	0.5978	0.8476	141.7830

Source: Source: Sample Survey of Dairy Households in the Marginal zones of Kenya, June-September, 2006.

Table 6.2: The shares of variable inputs and output in dairy production on sample farms

Variable Description	Mean	Std. Deviation	Coefficient of variation (%)
Protein input share	0.8852	1.3296	150.2033
Roughage feed share	1.8568	2.8616	154.1168
Health input share	0.1028	0.1474	143.4496
Tick input share	0.1436	0.2154	149.9956
Labour input share	1.6523	2.6383	159.6758
Milk output share	5.6406	6.4354	114.0909

Source: Source: Sample Survey of Dairy Households in the Marginal zones of Kenya, June-September, 2006.

determined. Overall, there are high percent variations in the use of the various inputs in dairy production. A similar trend is observed in the input shares. The differences in prices can possibly be attributed to differences in socio-economic and institutional factors facing individual farms.

6.3. Translog Profit Function-Input Demand Systems Model Results

The systems analysis model consisting of the translog profit function and S_i equations for protein feeds, roughage feeds, tick control, cattle treatment and labour with cross equation restrictions of homogeneity in input prices, symmetry and adding up property is estimated using cross-sectional data for the period July 2005 to June 2006. The restriction of linear homogeneity in the input prices is imposed by normalizing the profit and the input prices by the output price of milk. The estimated parameters of the system and the associated asymptotic z-values are reported in Table 6.3. All the input price coefficients have the expected negative signs as required by theory. However, only the protein feed price and treatment price are significant at 5 percent. Roughage feeds price, tick price and labour wage rates are insignificant. Grazing area has the expected negative sign and is significant at 1 percent. The number of school years for the dairy manager has a negative effect on profits although it is insignificant. This finding reinforces the results of Chapter 4 where the number of school years increases cost inefficiency and ultimately reduces profits. Extension influences profits positively as expected but it is insignificant. The walking distance ratio to the tarmac road significantly impacts dairy profits at 1 percent level. The parameter has the expected negative sign. The number of dairy cows, as expected affects profits positively and significantly at 1 percent level. The distance to the water point has unexpected positive sign. However, the parameter has insignificant effect on profits.

In summary, it is quite evident that the results of the profit function approach corroborate those of cost inefficiency analysis in Chapter 4 and cost function systems approach in Chapter 5. It is noticeable that the impacts of the key institutional and socio-economic factors on the normalized profit corroborate very closely to the impacts these same factors have on the cost of production in Chapter 4.

Table 6.3: Restricted Parameter Estimates of the Translog Profit Function of Dairy Farms in Marginal Zones

Variable description	Parameters	Coefficient	Standard Error	|P[|Z|>z] |
Constant	α o	8.989821	1.241105	0.000000
Ln protein feeds price	α1	-0.603825	0.297183	0.042200
Ln roughage feeds price	α 2	-0.036735	0.170419	0.829300
Ln tick administration price	α3	-0.271030	0.732737	0.711500
Ln treatment administration price	α 4	-0.789021	0.319692	0.013600
Ln wage rate	α5	-0.233614	0.603504	0.698700
Ln grazing acre	α6	-1.495437	0.431893	0.000500
Ln school years	α7	-0.006535	0.078428	0.933600
Ln extension	α8	0.257622	0.177241	0.146100
Ln walking ratio	α9	-4.487264	1.287484	0.000500
Ln number of cows	α10	0.959776	0.320285	0.002700
Ln water distance	α11	0.148062	0.299153	0.620600
Squared protein price	β1	0.115604	0.084319	0.170400
Squared roughage price	β2	-0.245191	0.052533	0.000000
Squared tick price	β3	-0.065500	0.228337	0.774200
Squared health price	β4	0.051228	0.091619	0.576100
Squared labour price	β5	-0.896960	0.412682	0.029700
Squared grazing area	β6	0.073087	0.073303	0.318700
Squared education	β7	-0.001652	0.005043	0.743200
Squared extension visit	β8	0.000364	0.001387	0.792800
Squared walking ratio	β9	4.018325	1.241972	0.001200
Squared water distance	β10	0.167444	0.076835	0.029300
Squared number of cows	β11	-0.022844	0.012975	0.078300
Protein –roughage cross	γ12	0.013699	0.036985	0.711100
Protein –tick cross	γ13	-0.019718	0.159879	0.901800
Protein –health cross	γ14	0.069487	0.055478	0.210400
Protein –labour cross	γ15	0.026122	0.117528	0.824100
Protein –acre cross	γ16	0.102993	0.052811	0.051200
Protein –education cross	γ17	-0.000679	0.000414	0.100900
Protein –extension cross	γ18	-0.001075	0.000984	0.274700
Protein –walking ratio cross	γ19	0.358633	0.206266	0.082100
Protein –water cross	γ110	0.001302	0.001001	0.193300
Protein –cow cross	γ111	-0.062775	0.033157	0.058300
Roughage –tick cross	γ23	-0.140243	0.092579	0.129800
Roughage –health cross	γ24	0.096508	0.046047	0.036100
Roughage –labour cross	γ25	0.457543	0.102389	0.000000
Roughage –acre cross	γ26	0.167387	0.057924	0.003900
Roughage –education cross	γ27	0.027169	0.009930	0.006200
Roughage –extension cross	γ28	-0.000670	0.000516	0.194300
Roughage –walking ratio cross	γ29	-0.258326	0.111833	0.020900
Roughage –water cross	γ210	0.000068	0.000639	0.914800
Roughage –cow cross	γ211	-0.081451	0.030583	0.007700
tick –health cross	γ34	0.117520	0.108906	0.280500
tick –labour cross	γ35	0.642770	0.393242	0.102100
tick –acre cross	γ36	0.073562	0.096569	0.446200
tick –education cross	γ37	0.031913	0.026506	0.228600

Table 6.1 (continued)

Variable description	Parameters	Coefficient	Standard Error	|P[|Z|>z] |
tick –extension cross	γ38	-0.097453	0.049646	-1.963000
tick –walking ratio cross	γ39	0.165843	0.288438	0.575000
tick –water cross	γ310	0.030487	0.127103	0.240000
tick –cow cross	γ311	0.110306	0.060026	1.838000
Health–labour cross	γ45	-0.199206	0.098832	-2.016000
Health –acre cross	γ46	0.149267	0.069448	2.149000
Health –education cross	γ47	0.000712	0.000697	1.022000
Health –extension cross	γ48	-0.004447	0.032145	-0.138000
Health –walking ratio cross	γ49	0.508210	0.165169	3.077000
Health –water cross	γ410	0.000284	0.000763	0.373000
Health –cow cross	γ411	-0.004060	0.029705	-0.137000
labour –acre cross	γ56	-0.621628	0.186586	-3.332000
labour –education cross	γ57	0.010407	0.051376	0.203000
labour –extension cross	γ58	-0.027267	0.095122	-0.287000
labour –walking ratio cross	γ59	0.317950	0.496114	0.641000
labour –water cross	γ510	0.128672	0.183447	0.701000
labour –cow cross	γ511	0.404881	0.224587	1.803000
acre –education cross	γ67	0.011891	0.013828	0.860000
acre –extension cross	γ68	-0.011163	0.015563	-0.717000
acre –walking ratio cross	γ69	0.414144	0.140919	2.939000
acre –water cross	γ610	0.136515	0.066034	2.067000
acre –cow cross	γ611	-0.031341	0.038518	-0.814000
education –extension cross	γ78	-0.012071	0.004868	-2.480000
education –walking ratio cross	γ79	0.053685	0.029175	1.840000
education –water cross	γ710	-0.026380	0.021393	-1.233000
education –cow cross	γ711	0.007561	0.007185	1.052000
Extension –walking ratio cross	γ89	-0.201538	0.051056	-3.947000
Extension –water cross	γ810	-0.037334	0.037635	-0.992000
Extension –cow cross	γ811	0.001096	0.006220	0.176000
Walking ratio –water cross	γ910	-0.074148	0.196242	-0.378000
Walking ratio –cow cross	γ911	-0.105894	0.094721	-1.118000
Water distance –cow cross	γ1011	-0.056501	0.080284	-0.704000
Value of log-likelihood function		-701.8500		
Number of observations		134		

Source: Source: Sample Survey of Dairy Households in the Marginal zones of Kenya, June-September, 2006.

6.4. Hypothesis Testing

The adequacy of the translog profit function simultaneously estimated with the input demand system is evaluated by testing four hypotheses. The results are presented in Table 6.4. The first hypothesis tests for a suitable functional form between the restrictive Cobb-Douglas versus the flexible translog function. The Cobb-Douglas functional form is

Table 6.4: Likelihood Ratio Tests

Null hypothesis	Restricted log likelihood	Unrestricted log likelihood	Computed Statistic	No. of restrictions	Critical table value	p-value	Decision
Test for functional form: The Cobb-Douglas function is not different from the translog function	-0.1939	-0.1451	0.9760	66	0.3841	0.0069	Reject H_0
The input demand system with cross equation equality restrictions is not different from the translog-input demand system with restrictions:	-701.850	-662.393	78.9136	1	3.84145	0.0000	Reject H_0
The input demand system without cross equation equality restrictions is not different from the translog-demand system with restrictions:	-701.850	-631.933	139.8333	61	3.8414	0.0000	Reject H_0
Test of symmetry: The input demand system with and without cross equation equality symmetry restrictions is not different:	-662.393	-631.933	60.9197	20	3.8414	0.0005	Reject H_0

Source: Source: Sample Survey of Dairy Households in the Marginal zones of Kenya, June-September, 2006.

significantly rejected at 1 percent level in favor of the translog functional form. The Cobb-Douglas functional form also violates the theoretical expectations of the parameter signs. Therefore the translog functional form is used for the supply analysis. The second hypothesis attempts to establish whether the translog profit function is a simultaneous system with the input demands in the production process. The hypothesis tested is of the cross equation restrictions in the share equations by estimating them as a system without the profit equation. The null hypothesis is that there is no difference between estimating the input demand system and estimating the translog cost-input demand system simultaneously, both the systems with cross equations restrictions. The null hypothesis is rejected in favor of simultaneous estimation of the profit function and input demand system. These results imply that smallholder dairy production, supply and input demands are adequately integrated as a system.

The third null hypothesis is that parameters of the five demand equations are equal to the corresponding same parameters in the profit function. This is a joint hypothesis on the validity of imposing sixty-one restrictions to estimate the profit function and the input demands simultaneously as a system. The null hypothesis is rejected in favor of the translog profit-input demand equations as a simultaneous system where parameters in the profit function are equal to those in the input demand system. The fourth null hypothesis tests for imposition of symmetry in the input demand equations. It specifies that estimates of the input demand system of equations without cross equation equality symmetry restrictions is not different from estimates of the input demand system of equations with cross equation equality symmetry restrictions. This hypothesis is also rejected in favor of imposing symmetry in the input demand system of equations. These results imply that the validity of imposing cross equation equality restrictions and symmetry in the input demand system and estimating them simultaneously with the translog profit function cannot be rejected at 1 percent level. It is also observed that very large gains in estimation efficiency of the system follow when the cross equation restrictions are imposed. These results indicate that production, supply, and input demands are an integrated simultaneous system of activities in dairy production. These findings imply, among other things, that the sample farms, on an average, maximize profits with respect to normalized prices of the variable inputs, thus supporting empirically the assumption of profit maximization.

6.5. Elasticity Estimate Results

The parameter estimates presented in Table 6.3 form the basis for deriving elasticity estimates related to output supply, profit of dairy production and input demand for the variable inputs of protein feeds, roughage feeds, tick control, animal treatment, and labour. The elasticity estimates are presented in Table 6.5 . They are obtained by using equations 3.23 up to equation 3.30 in Chapter 3 Section 3.4.2. They are functions of variable input shares, variable input prices, levels of fixed inputs, and the parameter estimates of the translog profit function presented in Table 6.3. These elasticities are evaluated at simple averages of the input shares (S_i) and at geometric means of the variable input prices and of the level of fixed inputs. With this assumption, the elasticity estimates become linear transformations of the parameter estimates of the translog profit function, and asymptotic Chi-square value can be computed to test for their significance by imposing linear

Table 6.5. Estimated Elasticities of Translog Profit Function

Price/non-Price factors	Supply of Output	Protein feed demand	Roughage feed demand	Tick control demand	Demand for Treatment	Labor demand	Profit
Milk price	8.447485***	18.347659***	5.432767***	27.257184***	9.265917***	7.707584***	6.918932
	(0.533667)	(1.307477)	(0.623327)	(8.059742)	(1.049491)	(0.700465)	
Protein price	-2.879365***	**-12.040894*** **	-2.628464***	-3.131430***	-3.298629**	-2.568353***	-2.449679
	(0.205187)	**(1.402061)**	(0.668410)	(1.085261)	(1.125412)	(0.751137)	
Roughage price	-1.788385***	-5.513481***	**-2.531603*** **	6.463743***	-1.086187	-0.435301**	-7.157872
	(0.205187)	(1.40206)	**(0.160051)**	(2.069521)	(2.89088)	(0.179860)	
Tick price	-0.693921***	-3.045531***	0.499888***	**-0.887787**	-1.387115	-1.113368 ***	-1.894087
	(0.205187)	(0.335724)	(0.160051)	**(1.186758)**	(1.657767)	(0.103140)	
Treatment price	-0.828031***	-3.109499***	-0.060135	-0.993004	**-1.533677**	-2.487860***	-3.501132
	(0.205187)	(0.192519)	(0.091780)	(1.186758)	**(7.127792)**	(0.443464)	
Wage rate	-2.257781***	-4.794048)***	-0.387358	-3.053444***	-2.904201***	**-2.174771*** **	-6.952917
	(0.205187)	(0.827764)	(0.394623)	(0.640728)	(0.664433)	**(0.193483)**	
Grazing area	21.021097***	9.034304***	-1.437736	14.024740***	8.001091***	6.876338***	0.388837
	(1.159037)	(1.719896)	(3.010899)	(3.449379)	(1.731764)	(2.134441)	
Education	18.307972***	8.671277***	5.529701***	-2.302677	-8.801970***	4.379563**	-0.882147
	(1.096135)	(1.704290)	(2.102129)	(3.437349)	(3.548885)	(2.119354)	
Extension visits	16.420333***	11.688364***	9.407854***	1.071799	-11.065347***	8.068382***	-0.57402
	(1.086064)	(1.869561)	(2.176565)	(3.411535)	(3.518724)	(2.191360)	
Walking ratio	-8.941067***	-15.62046***	-16.67541***	2.885449	-21.558419***	22.499677***	-1.661317
	(1.061337)	(1.582917)	(2.13471)	(3.003671)	(3.712371)	(2.110016)	
Distance to water	-7.771938***	0.131763	-0.573232	19.972109***	5.685312*	25.078464***	-1.661536
	(1.924270)	(1.582917)	(2.265803)	(3.099519)	(3.197629)	(2.108403)	
Number of cows	31.692338***	22.831561***	20.940891***	15.575116***	6.808985*	20.553733***	1.99814
	(1.151324)	(1.777083)	(1.9302676)	(3.065945)	(3.17060)	(1.941779)	

Source: Sample Survey of Dairy Households in the Marginal zones of Kenya, June-September, 2006.

constraints on the appropriate parameters of the model (Sidhu and Baanante, 1981). In the current analysis, the WALD procedure (Green, 2002) is used to compute the elasticity coefficient estimates and standard errors for nonlinear functions and joint test of nonlinear restrictions imposed. Estimates of dairy supply and variable input demand elasticities for protein feeds, roughage feeds, tick control, animal treatment and labour with respect to milk output price, variable input prices and fixed inputs are valuable results in themselves, as they indicate the expected responsiveness of farmers to changes in market prices, institutional and socio-economic variables as possible levers for regional-policy actions to enhance expansion of dairy production.

The results in Table 6.5 show that the impact of any of the exogenous variables varies across input demand functions. Most of the elasticity coefficients are quite elastic, and relatively few of them are inelastic. The variable input elasticity coefficients are negative except roughage price and tick control and tick control administration price and roughage feed. This finding implies that most of the inputs are complements except roughage feed and tick controls which are substitutes. The elasticity coefficients of the socio-economic and institutional factors tend to impact output supply positively except infrastructural variables which have a negative influence on output and some of the input demands. All the supply and input demand elasticity coefficients except fourteen of them are significant. It is important to note that some of the input demand and output supply elasticities look relatively large. However, the actual respective quantity increases or decreases are relatively small due low levels of resource use in dairy production as seen in the reported descriptive statistics in the study. It can be recalled that smallholder dairy production in the marginal areas is a relatively new technological package adopted from the high potential zones of Kenya. These results possibly imply that farmers are still learning the art of dairy husbandry and are quite responsive to the various price and non-price factors which can influence the expansion of dairy production. In particular, it is observed that the non-price factors i.e. institutional and socio-economic factors appear to be important in influencing smallholder dairy supply. The various impacts of price and non-price factors are discussed in the following sub-sections.

6.5.1. Impacts of Price Factors

One of the possible key policy variables is the price of milk. The output response of farmers in the marginal areas to increases in the milk price is found to be positive, as expected, and elastic; a one per cent increase in the price of raw milk would expand its supply in the marginal zones by 8.45 per cent. This is the responsiveness of milk output supply resulting from a 1 percent increase of all variable inputs and management while maintaining the fixed inputs such as the number of cows constant. This elasticity coefficient sounds like a big increase in milk output. However, it would make average milk output in the marginal zones to increase by only 121.11 litres per cow from 1424.88 litres to 1545.99 litres, which is still below the average potential annual milk output of 4,000 to 6,000 litres per cow. Increases in the raw milk price would also encourage direct and significant expansion in demand for all variable inputs. In quantitative terms, the per cent increase in demand for variable inputs associated with one per cent increase in raw milk is: protein feeds (18.35), roughage feeds (5.43), tick control (27.25), animal treatment (9.26) and labour (7.71). Increases in milk output price also has a similar impact on dairy profits. It increases by 6.92 per cent for every one per cent increase in milk output price.

Turning to the response of changing input prices, it is observed that the estimated own-price elasticities of demand for variable inputs are negative, as suggested by theory. The own- elasticities of animal feeds and labour are statistically significant, but those of animal health i.e. tick control and animal treatment are insignificant. These inputs are price elastic except the tick control price. They range from -12.04 for protein feeds to -0.89 for tick control. Increasing the price of variable inputs would also have a significant depressing impact on the supply of raw milk for all the variable inputs. The largest supply response effect is -2.88 for changes in protein feeds price and the lowest is -0.69 for changes in tick control price. A similar impact is observed on dairy profits with respect to changes in variable inputs.

The cross-price elasticities show that all the coefficients except that of roughage price and tick control, and tick price and roughage feeds are negative. They range from -5.51 for protein feeds- roughage price to -0.06 for roughage feed demand-treatment coefficient. Thus, most of the inputs in dairy production are complements; they tend to be used together in production. But tick demand-roughage price and roughage demand-tick control price are substitutes with coefficients 6.46 and 0.49 respectively. A possible explanation for this finding is that if prices of roughage feeds go up, the quantity of roughage demanded goes down. This is because most of the farmers opt to graze their cows. The marginal zones have higher incidences of ticks than the high potential zones due to hot climate. Since cattle ticks are on grass fields, the higher the frequency of grazing, the higher the incidence of ticks. Hence, the two are substitutes. All cross price elasticities are elastic except roughage demand-tick price and labour wage coefficients, and tick control demand–treatment price coefficients. These elasticities are also significant except treatment price and labour wage coefficients in roughage feed demand, treatment price coefficient in tick control demand and roughage price and tick price coefficients in demand for treatment. In sum, changes in market prices, whether input or output prices significantly affect resource use and raw milk supply although the impact in quantitative terms for tick and treatment prices in some of the input demand cases are relatively muted.

6.5.2. Impacts of Non-Price Factors

An amplified picture emerges in terms of the role of fixed inputs which are the institutional and socio-economic factors included in the translog profit systems model approach (Table 6.5). Most of the estimated parameters associated with these variables have the expected signs. It is also observed that the majority of these non-price factors are statistically significant and have relatively large elasticity coefficients compared to market price factors. A panoramic view of the elasticity coefficients seems to indicate that dairy expansion in the marginal zones is more responsive to institutional and socio-economic non-price factors than to the market price factors.

In quantitative terms, the percent increase in raw milk output supply associated with one per cent increase in the non-price factors is positive and largest for the number of milk cows (31.69), followed by grazing area (21.02), education years of the dairy manager (18.31), and the number of extension visits (16.42). However, a one percent increase in each of the infrastructural factors has a negative impact on milk supply with the ratio of walking distance to the tarmac having -8.94 per cent and distance to the water point -7.77 per cent.

Turning to the response of input demands to changing non-price fixed factors, we find that an increase of grazing area by one per cent increases the demand for most of the other inputs: protein feeds (9.03 %), tick control (14.02%), treatment (8.00 %) and labour

(6.87 %). If the demand for grazing increases, the demand for labour to look after the cows in the fields increases also. The demand for tick control increases as well because the cows are grazing in grass fields with relatively high tick incidences in the marginal zones unlike in the high potential areas. Consequently, disease incidences increase with cattle grazing and hence higher demand for treatment. However, the demand for roughage feeds decreases (-1.44 %) with increase in grazing area even though the coefficient is insignificant.

The dairy managers' education also influences the demand for inputs. If the number of years of education increases by one per cent, the input demands increase by 18.31 per cent for protein feeds, 5.52 per cent for roughage feeds and 4.37 per cent for labour. Hence education increases the demand for feed and labour use. However, increased education results in reduction in demand for tick control (-2.30 per cent) and demand for treatment (-8.80 per cent). This finding implies that managers with relatively high education grasp health management skills for dairy cows adequately, which results in reduced tick and disease incidences.

Increasing the number of extension visits by one per cent increases the demand for protein feeds (16.42 per cent), roughage feeds (9.41 per cent), tick control (1.07 per cent) and labour (8.06 per cent). However, it reduces demand for cattle treatment (-11.06 per cent). Thus, the influence of extension is quite important. It increases the demand for most of the variable inputs, but more importantly, for protein feeds and reduced animal treatment.

One of the key non-price policy variables influencing smallholder dairy expansion in the marginal zones seems to be the infrastructure variable. It is represented by the walking ratio to the tarmac road and the distance to the water point for the dairy cows. The input demand response of dairy farmers in the region to a one per cent increase in the walking ratio to the tarmac road is quite significant and has a negative impact on protein feeds (-15.62 per cent), roughage feeds (-16.67 per cent) and treatment (-21.55 per cent). But, it has a positive and significant impact on demand for labour (22.49 per cent). However, it has no significant effect on tick control. These results imply that the portion of distance which the farmers have to walk to the tarmac road posses a serious drudgery to dairy expansion. The longer this distance is, the less the demand for feed and treatment inputs. However, it requires more labour to carry the feeds through the walking distance to the homestead. The distance to the water point for the dairy cattle is another non-price factor influencing dairy expansion. A one per cent increase in water point distance increases demand for tick control by 19.97 per cent and labour demand by 25.07 percent. Also, the demand for animal treatment increase by 5.68 per cent. However, it has no significant impact on protein and roughage feeds. This means that long distances to the watering point increases tick and animal disease incidences and requires more labour.

Expansion of the number of dairy cows is an important source of resource employment in the marginal zones. An increase in the number of cows causes an increase in demand for all the inputs. These input demands are all significant and quite elastic. The per cent increase in demand for variable inputs associated with one per cent increase in the number of dairy cows is largest for protein feeds (22.83 per cent), roughage feeds (20.94 per cent), tick control (15.57 per cent), treatment (6.81 per cent) and labour employment (20.55 per cent). It is also observed that most of the non-price fixed factors have a negative effect on profits. However, grazing area and the number of cows have a positive influence.

6.6 Conclusions and Recommendations

6.6.1 Conclusions

Kenya's stated policy is to increase dairy production through liberalization of input and output markets. The purpose for this section of the study has been to assess the performance of smallholder dairy production in the marginal zones within a liberalized market environment. The main objective is to determine how government policy might best be focused to achieve output expansion goals in dairy production. The study determines the impacts of price and non-price factors on output supply, profit and input demands in an effort to explore possible ways of enhancing these factors to expand dairy production.

The analysis in this section is based on a normalized restricted translog profit function and the derived system of demand equations for variable inputs. In the view of the liberalized market environment for the dairy sector in Kenya, the neoclassical duality theory is extensively exploited as the most appropriate study framework for this analysis. The translog profit function was estimated jointly with the dairy input demand equations by using Zellner's (1962) systems analysis of seemingly unrelated regression method which provides asymptotically more efficient estimates than the production function estimates given by the principle of ordinary least squares. The method is implemented by using Limdep (Green, 2002). The analyses uses cross-sectional survey data collected for the period July 2005 to June 2006. In addition to the variable inputs of protein feeds, roughage feeds, tick control, animal treatment and labor, and the fixed input of grazing area, a few other institutional and socio-economic variables measured by education, number of extension visits, walking ratio to the tarmac road, distance to the water point and the number of dairy cows were included in the model. Various hypotheses are tested to establish whether the smallholder dairy farms uphold the assumption of profit maximization in the marginal zones.

The hypotheses of the cross equation restrictions in the profit share equations are tested by estimating them as a system without the profit function equation, and with and without the cross equations equality restrictions. A likelihood ratio test is used to test the hypotheses. Without the assumption of restrictions, the profit share equations have no theoretical basis (Green, 2002). The results showed that the symmetry restrictions cannot be rejected. It also emerges that the validity of cross equation equality constraints in the input demand system and estimating them simultaneously with the translog profit function cannot be rejected at the 1 per cent level of significance. This implies, among other things, that the sample farms, on an average, maximize profits with respect to normalized prices of the variable inputs, thus supporting empirically the assumption of profit maximization. It is therefore concluded that the empirical analysis of smallholder dairy production reported in this section has yielded broadly satisfactory results both in terms of economic theory and statistical fit. The estimated parameters of the translog-input demands then form the basis for deriving elasticity estimates related to output supply, input demands and profit of dairy production.

The output response of dairy farmers to increases in the milk price is found to be positive, as expected, and quite elastic. A one per cent increase in the price of raw milk would expand its supply by 8.45 per cent. Increases in the raw milk price would also stimulate direct and significant expansion in demand for all variable inputs. The per cent increase in demand for variable inputs associated with one per cent increase in raw milk ranges between 18.35 % for protein feeds to 5.43 % for roughage feeds, whereas profits increase by 6.92 %. The response of changing input prices show that the estimated own-price elasticities of demand for variable inputs are negative, as suggested by theory. The own- elasticities of animal feeds and labour are statistically significant, but those of animal health are insignificant. These inputs are price elastic except the tick control price. They range from -12.04 for protein feeds to -0.89 for tick control. Increasing the price of variable inputs would also have a significant depressing impact on the supply of raw milk for all the variable inputs. The largest supply response effect is -2.88 for changes in protein feeds price and the lowest is -0.69 for changes in tick control price.

The cross-price elasticities show that most of the inputs in dairy production are complements. All the coefficients except those of tick control demand-roughage price and roughage feeds demand-tick price are negative, and range from -5.51 for protein feeds-roughage price to -0.06 for roughage feed demand-treatment price coefficient. The coefficients of tick demand-roughage price and roughage demand-tick control price are 6.46 and 0.49 respectively and they are substitutes. All cross price elasticities are elastic except roughage demand-tick price and labour wage coefficients and tick control demand–treatment price coefficients. These elasticities are also significant except treatment price and labour wage coefficients in roughage feed demand, treatment price coefficient in tick control demand and roughage price and tick price coefficients in demand for treatment. In sum, changes in market prices, whether input or output prices significantly affect resource use and raw milk supply although the impact is relatively muted for a few of the price variables .

The results of price elasticities lead to the conclusion that dairy farmers are quite responsive to input and output price changes. This response can perhaps be attributed to the substantial liberalization of the dairy sector in Kenya. The markets have been subjected to the forces of supply and demand much more than formally. Expectations are that sustained liberalization will continue to enhance efficient allocation of resources and improve the producer and consumer welfare. To achieve net social benefits, the market must be efficient.

The role of non-price fixed inputs in smallholder dairy production is quite emphatic. Most of the estimated parameters associated with these variables have the expected signs. It is also observed that the majority of these non-price factors are statistically significant and have relatively large elasticity coefficients compared to market price factors. A panoramic view of the elasticity coefficients seems to indicate that dairy expansion in the marginal zones is more responsive to non-price factors than the market price factors. The percentage increase in raw milk output supply associated with one per cent increase in the non-price factors is positive and largest for the number of milk cows (31.69), followed by grazing area (21.02), education years of the dairy manager (18.31), and the number of extension visits (16.42). However, the infrastructural factors have a negative impact on milk supply with the ratio of walking distance to the tarmac having -8.94 per cent and distance to the water point -7.77 per cent.

Turning to the response of input demands to changing non-price fixed factors, we find that an increase of grazing area by one per cent increases the demand for most of the other inputs: protein feeds (9.03 %), tick control (14.02%), treatment (8.00 %) and labour (6.87 %). However, the demand for roughage feeds decreases by -1.44 %. If the number of years of education increases by one per cent, the input demands increase by 18.31 % for protein feeds, 5.52 % for roughage feeds and 4.37 % for labour. However, the demand for tick control decreases by -2.30 % and by -8.80 % for animal treatment. The responsiveness of input demand to a one per cent increase in the number of extension visits is: 16.42 % for protein feeds, 9.41 % for roughage feeds, 1.07 % tick control and 8.06 % for labour. However, it reduces demand for cattle treatment by -11.06 %.

The infrastructural variables have a pronounced negative impact on dairy production in the marginal zones. A one per cent increase in the walking ratio to the tarmac road leads to reduction of protein feeds (-15.62 %), roughage feeds (-16.67 %) and treatment (-21.55 %). But it has a positive and significant impact on demand for labour (22.49 %) and no significant effect on tick control. The distance to the water point for the dairy cattle is another non-price factor influencing dairy expansion. For a one per cent increase in water point distance, demand for tick control increase by 19.97 %, labour demand by 25.07 % and animal treatment by 5.68 %. But it has no significant impact on protein and roughage feeds. On the other hand, expansion of the number of dairy cows is an important source of input employment in the marginal zones. The demand for protein feeds increase by 22.83%, roughage feeds by 20.94 %, tick control by 15.57 %, treatment by 6.81 %, and labour employment by 20.55 % for a one per cent increase of the number of dairy cows.

The results of fixed input elasticities draw quite an emphatic picture in relation to the role of non-price factors in smallholder dairy production. The conclusion emerging from these results is that dairy farmers are more responsive to non-price factors than to price factors. It therefore implies that while there is a need for a consistent and a sustained liberalization program in the dairy sub-sector, it is also necessary to reinforce the liberalization policies already in place by increasing public expenditure on rural infrastructure, particularly the road net work, rural water supply, strengthening of extension services, human resource development and other agricultural support services in the marginal zones.

6.6.2 Recommendations and Policy Implications

The final thrust of this study has been to determine the supply response of the smallholder dairy farms in the marginal zones of Kenya. The analytical results imply, among other things, that dairy farms, on average, maximize profits with respect to normalized prices of the variable inputs, thus supporting empirically the assumption of profit maximization. Therefore, it can be concluded that farmers in the marginal zones have adopted dairy technological packages with an objective of maximizing profits. Further, the results of price elasticities lead to the conclusion that dairy farmers are quite responsive to input and output price changes. However, non-price factors seem to have a greater impact on output and input demands than the price factors. It is therefore concluded that more efficient input and output dairy markets would enhance dairy expansion in the marginal zones. In addition, judicious investment in physical and institutional infrastructure that has public good attributes can aid the performance of dairy production and marketing system in the marginal zones. Given the empirical findings of this analysis and the conclusions reached, a number of possible policy areas of intervention are suggested for attention:

(1) Enhancing efficiency of raw milk output markets: The results of this study have shown that dairy farmers are quite responsive to price changes. For instance, the quantity of raw milk output would increase by 8.45 per cent if its price increases by one percent *Ceteris Paribus*. Also, increases in the raw milk price would stimulate

direct and significant expansion in demand for all variable inputs. These findings can be used to enhance the efficiency of raw milk output markets and expand dairy production in the marginal zones.

A major policy change to take place in the dairy sector in Kenya is the policy of price decontrol which was affected in 1993. Over the intervening period, the dairy industry has undergone substantial liberalization with the markets being subjected to the forces of supply and demand much more than formally. The thrust of the industry liberalization was to create equitable and efficient markets which are vital for rural development. It is hoped that a sustained and continued liberalization program will foster efficient allocation of resources thereby, expanding dairy production and improving both producer and consumer welfare in the marginal zones.

The next level of the liberalization program needs to rationalize the multiple forms of charges on farmers' income which are paid to the various government agencies. These deductions distort output prices and result in low prices of milk per litre to the farmers. As a result, dairy output markets are not efficient. Inefficiency in milk output markets is suspected to be one of the factors hindering the expansion of the sector in the marginal zone. The various levies are paid to Kenya Dairy Board (KDB), Kenya National Federation of Agricultural Producers (KENFAB), County/Municipalities, Public Health Inspectorate and Kenya Revenue Authority. Table 6.6 shows the levies paid by the three of the cooperative societies in 2006 and the corresponding services rendered. In addition to the above levies, the societies have to pay 16 per cent of their

Table 6.6: Levies Paid by Farmers and Services Rendered in 2006

Public Agency	Dairy Cooperative 1	Dairy Cooperative 2	Dairy Cooperative 3
	Kshs	Kshs	Kshs
Kenya Dairy Board-License	9000.00	9000.00	9000.00
-Cess	95166.40	132666.10	43659.00
Cooperative related charges	15000.00	23200	27000.00
County/ Munincipal council charges	60300.00	67330	6000.00
Public health inspectorate	1200.00	900	300.00
Milk Output ((Litres)	475832	662899.50	218295

Source: Dairy Cooperative Societies in the Marginal Zones of Kenya, 2006.

profits to Kenya Revenue Authority. If all the charges[7] are put together, then farmers remit Kshs. 0.75 per litre (approximately 3.75% of the price they are paid) to the various government agencies. However, the services offered in return are minimal or none existent. Only one cooperative society reported training of two staff members on computer basics and a promise to donate a computer by one of the agencies.

On the basis of the stochastic frontier analysis in Chapter 4, the inefficiency model gives the marginal benefit side of cost reduction for various services [e.g. dairy records (-11.82 %), feed storage (-14.20%), use of credit (-12.58%) and walking distance ratio (17.76%)] and not the cost side. Therefore, from a benefit perspective in return for the payment of 3.75 % by farmers, reduction of the walking ratio distance to the tarmac road seems to give the highest value to the farmer. But, it is the highest value per unit cost of service provision which matters. However, this study did not measure the costs of providing services. So, one cannot conclusively recommend a service or practice for the farmers. Nevertheless, one can deduce what service or practice without being conclusive. The services paid for by farmers should improve their welfare and/or their dairy production. It is therefore recommended that these levies be reviewed and rationalized with respect to the services rendered to or on behalf of farmers. The review should be aimed at lowering the levies paid by farmers. Ultimately, it would increase the price of milk per litre and enhance dairy expansion in the marginal zones.

2) Agribusiness opportunities to take advantage of milk components i.e. proteins and fats: When Friesian and Jersey provide a litre of milk, the Jersey has more real value due to more fats and proteins. However, raw milk in Kenya is given a uniform price regardless of the milk quality composition from different cattle breeds. This causes country wide inefficiency in raw milk pricing. So, if one creates a business and takes advantage to market the components, it would add value to the dairy industry in Kenya.

3). Enhancing efficiency of protein feed markets: Protein feed use is found to be particularly important in the decisions on resource allocation in smallholder dairy production. Compared with the other variable inputs, the elasticity of demand for protein feeds with respect to output price (i.e. 18.35%) is the second highest. The milk output supply elasticity with respect to protein feeds price (-2.88%), and the own-price elasticity of demand for protein feeds (-12.04%) are the highest. The cross-price elasticities of the variable input demands with respect to protein feed price show a similar trend: it is the second highest in tick control demand (i.e. -3.13 %) and the highest in the other input demands. In addition, the results of this study have revealed that relatively small quantities of protein feed per cow per day (i.e. 1.16 kilograms of concentrates, 43.82 grams of mineral salts and 3.63 grams of milking serve) are used

[7] *Information on audit details and tax payments by cooperatives could not be divulged.*

in production. Based on these results, it is recommend that the efficiency of the livestock feed industry and how it affects dairy feed uptake be undertaken. If the livestock feed industry is efficient, it would realize competitive and affordable prices which would stimulate the use of dairy feeds.

Since the liberalization of the dairy industry, the use of manufactured feeds and feed supplements has increased. Consequently, the size of the animal feed industry has been steadily increasing. There are approximately 39 registered provender millers, oilseed millers and feed premix suppliers of which 10 are cereal grain millers, 8 are oil seed millers, 15 are registered raw material importers and 6 are suppliers of feed premixes i.e. mineral, vitamin and other mineral elements (Radull, 2005). Most of the ingredients used in manufacturing feed industry in Kenya are imported. As an incentive to the industry, the government reduced import duty on oil seed cakes from 25 percent to 10 percent, and from 25 percent to 20 percent on imported fishmeal, cereal bran and other livestock feed ingredients in 2001. Despite these incentives, ingredient prices have remained high and in some cases continued to increase particularly the price of premixes. The government should probably revisit the issue of import duty on feed ingredients and reduce it further to influence the prices of animal feeds. Secondly, the number of firms in the feed industry looks relatively small. It is possible that they are influencing feed prices upwards. There is therefore need to investigate the performance of the animal feed industry in Kenya and put in place a "policy on livestock feed industry" to ensure relatively efficient livestock feed prices in the markets.

4) Judicious public investment in physical and institutional infrastructure: The fixed inputs are grazing area, education, extension, walking ratio, distance to water point and

the number of cows are found to be important factors contributing to the supply of milk. These non-price factors also influence significantly the demand for all variable inputs except in a few cases. Thus, besides the elastic supply response to raw milk price, the importance of allocating more land for grazing, education and extension to farmers, and the number of dairy cows accompanied by reduced walking distance ratio and distance to water point is all more evident. This further implies that in order to achieve higher milk output supply, besides the price policy measures, other non-price measures promoting the expansion of physical, socio-economic and institutional infrastructure are paramount. The smallholder dairy farmers are more dependent on these public services in the marginal areas where private sector participation is quite limited.

In sum, the choice of policy instrument has important implications particularly in a liberalized market environment. Strong incentives for increasing output may be expected to be created by price-based instruments on farther market liberalization. Within this group of instruments, those based on output prices have a great impact on input use intensity as well as output levels. Those focused on input prices may also influence output levels while offering the possibility of finer targeting of specific input increases e.g. protein feeds. However, instruments focused on institutional and socio-economic setups seem to offer more control over production methods and also offer powerful incentives of increasing output without concomitant increases in input intensity. In addition, they have broader impacts on input demands than the market price factors. Thus, to complement the liberalization policy already in operation, judicious investments in physical, socio-economic and institutional infrastructure can not be ignored in the marginal zones. However, they require greater utilization of public expenditure on rural infrastructure, rural water supply, extension services and other much needed rural agricultural support services such as keeping of farm records, credit availability and feed storage.

There is also need to put rural road infrastructure within the marginal zones in a regional perspective and determine the impacts of road net work on agricultural activities, output and returns. This would involve putting into consideration the type of business activities in the region, agricultural sector enterprises, amount of traffic, the current amount of roads (in kilometres) and their types i.e. tarmac, weather road, earth road and the population of the people affected by the transportation and the road net work system. This might involve the use of a regional general equilibrium model e.g. Computable General Equilibrium (CGE).

CHAPTER VII

GENERAL DISCUSSION AND CONCLUSIONS

7.1 Introduction

The economic performance of smallholder exotic dairy cattle in the marginal zones of Kenya is the theme of this study. This evaluation is analysed from three different but interrelated perspectives based on the specific research objectives outlined in Section 1.4. Smallholder exotic dairy cattle have been adopted in the marginal zones from the high potential areas of Kenya over the last two decades. It is a new alternative enterprise which offers higher returns to land and labour, has the potential for future growth, and is suitable for the resource poor smallholder farmers who continue to dominate agricultural production in the marginal zones. The challenge for the transition to the next stage is to expand and intensify dairy production and achieve the greatest possible output given the available resources and the new dairy technologies. This chapter concludes by highlighting the key economic issues arising out of this study. The chapter is organized as follows: Section 7.2 presents the summary of the study and its implications. Section 7.3 compares the results of the three approaches adopted for the study. Section 7.4 discusses overall policy implications and recommendations. Finally, Section 7.5 points out at the areas for future research work.

7.2. Summary and Implications

Kenya's Dairy experts in 1970s argued that the dry marginal zones could not meet the requirements of the high performing exotic breeds. They recommended that upgraded zebu breeds would be more suited to the marginal and semi-arid environments, even though their milk supply response capability is relatively low (Meyn and Wailkings, 1973;

Kimenyi and Russell, 1975). The use of larger breeds is generally discouraged because of their perceived higher nutritional demand, low milk yield, poor adaptability and low production performance under smallholder management conditions (Rege, 1998; Kahi *et al.*, 2000; Wakhungu, 2000).

The import of dairy industry in the marginal lands of Kenya cannot be overemphasised. There are no established cash crops like in the high potential areas where industrial crops such as tea, coffee and pyrethrum are grown. Neither are there off-farm employment activities such as tourism and fishery industries like in the coastal areas of Kenya. Therefore, alternative new agricultural activities which offer higher returns, offer the expectation of future growth, and are suitable for the resource poor smallholder farmers are needed (Nicholson *et al.*, 2004). Adoption of market oriented dairy production has filled this need in the marginal zones. Smallholder farmers in these areas have been compelled by continually changing technical, economic and policy environment to diversify from traditional subsistent staple food crops whose outlook for growth remains uncertain, to cash market oriented smallholder dairy production. Even though results from several dairy science studies discourage the use of high grade breeds, the contrary has continued to be observed (Syrstad, 1996; Rege, 1998; Wakhungu, 2000). The research problem statement is the continued establishment of high exotic grade dairy in the marginal zones in spite of the potentially low economic performance of these breeds in such relatively dry areas coupled with a dynamic agricultural environment.

Smallholder farmers in the marginal zones have experienced profound technical, economic and increasingly changing policy environment in the recent past. In such a dynamic system, farmers find it more difficult to adjust allocation decisions to keep pace with changes in their environment and at the same time, maintain an efficient allocation of resources. The combination of an evolving technical, economic and policy environment means that the equilibrium required for economic efficiency is a constantly moving target. In this new scenario, the scope for inefficiencies in resource use is much greater and hence development strategy may need to be re-examined. This study, therefore, examines the performance of dairy establishment and the possibilities of expansion in the marginal zones.

The goals of the study are to identify the socio-economic and institutional factors that influence efficiency of dairy practices, to determine the production structure and to determine the supply response of dairy farmers in the marginal zones. To achieve these objectives three interrelated approaches to production analysis are employed. The first approach uses the stochastic frontier framework to determine household, socio-economic attributes and institutional factors that influence cost inefficiencies and estimate their impacts. In the second and the third approaches, dairy production structure and supply response are analysed using the systems approach framework which permits measurement of different impacts that exogenous variables have within and across dairy input demands and raw milk supply .

The economic efficiency of dairy establishment is analysed by use of the stochastic translog cost function. An evaluation of the model showed that the estimated value of λ (lambda) is significant at 0.1 percent level which shows that the one-sided error term dominates the systematic error. Further, the estimated value of Gamma (γ) indicates that over 93 percent of random variation in the model is explained by inefficiency; pointing at a high level of inefficiencies in dairy establishment in the marginal areas. The test of the functional form between the Cobb-Douglas and translog forms shows that farmers do not exhibit the Cobb-Douglas technology. Hence, there are no constant returns to scale in smallholder dairy operations. Additional evaluations of the model shows that inefficiency effects are present, they are stochastic and are in a linear functional form in the model.

The analysis of the existing structure of dairy production and the associated supply response is based on the neoclassical duality results which are extensively used for this purpose. In the view of the liberalized market structure for dairy sector in Kenya, this is quite appropriate. The translog cost function is used to determine the structure of smallholder dairy production. On the other hand, the translog profit function approach is used to study the supply response of smallholder dairy farms. Each of the translog cost function and the profit function approaches is separately estimated jointly with the dairy input demand equations using Zellner's (1962) method. The systems analysis of seemingly unrelated regression provides asymptotically more efficient estimates than the principle of ordinary least squares. Several hypotheses are estimated with and without cross equation restrictions and imposition of symmetry in the input demand systems. The results show that the validity of imposing cross equation equality restrictions and symmetry in the input demand system and estimating them simultaneously with the translog cost or profit function cannot be rejected at 1 percent level.

Four main implications are apparent from this evaluation. The first one is that these findings imply, among other things, that the smallholder dairy farm establishment, on an average, maximizes profits with respect to normalized prices of the variable inputs, thus supporting empirically the assumption of profit maximization. The second implication is that the dairy farms do not embrace the Cobb-Douglas technology. Thus, there are no constant returns to scale in the smallholder dairy operations. Thirdly, there are significant levels of inefficiencies in the dairy establishment in the marginal zones, largely accounted for by institutional and socio-economic factors. Finally, the dairy farmers are more responsive to the institutional and socio-economic non-price factors than to price factors.

7.3. A Comparison of Results of the Three Approaches to Dairy Production Analysis

One of the assumptions in the in 1970s was that the high performing exotic breeds were not suitable for the marginal zones. However, the results of cost efficiency analysis show that exotic breeds are the most efficient. Ayrshire breed achieved the lowest cost inefficiency (24.36 %), Friesians (25.08%) and Jersey (25.54%). Sahiwal (28.43%) is the best among the indigenous breeds, followed by Guernsey. In terms of the cooperative societies, those in the marginal zone were most efficient i.e. Wamunyu (19.31%), Masii (19.38%) and Makueni (34.96%). The overall inefficiency for all the farms is 27.45 percent. Analysis of grazing systems showed that field grazing (22.13%) is the most efficient followed by semi-zero grazing (26.34%). The impacts of institutional and socioeconomic factors on cost inefficiency were evaluated and their associated marginal effects estimated. The results showed that older farmers, education above eight years of primary school and longer walking distances to the tarmac road are associated with high cost inefficiency whereas number of extension visits, keeping of dairy records, use of credit and lowland transitional zone are associated with low cost inefficiency. The marginal effects results show that various institutional and socio-economic factors would reduce average cost inefficiency: use of dairy records (11.82%), storage of feeds (14%), use of credit (12.58%), whereas a 1 perent increase in walking distance ratio to the tarmac road increases cost inefficiency by 17.76%. These findings seem to point out the need for improving institutional and socio-economic setups for the purpose of enhancing resource-use efficiency.

The results of the production structure show that most of the inputs in dairy are significant complements. However, protein feeds are insignificant substitutes in relation to roughage feed and own produced feeds demands. But with respect to protein feed demand, roughage feeds and own produced feeds are significant complements. The elasticity of substitution confirms that these feeds are Morishima substitutes. It seems that farmers purchase protein feeds merely to complement the other feeds. These results further indicate that farmers are quite responsive to input price changes.

The results of supply response analysis indicate that most of the dairy inputs are significant complements. In general, dairy farmers are quite responsive to market price factors. However, a panoramic view of the elasticity coefficients seems to indicate that dairy farmers are more responsive to non-price factors than the market price factors. The institutional and the socio-economic factors have statistically significant and relatively large elasticity coefficients compared to market price factors. These results indicate that future dairy expansion in the marginal zones will dependent more on the improvements of the institutional and socio-economic factors than the market price factors.

In conclusion, therefore, the results of the three analytical approaches complement each other. The systems analysis shows that farmers are responsive to market price factors. This implies that any price policy designed to stimulate supply would be expected to have a positive response. The results of the stochastic cost frontier indicate that the institutional and socio-economic factors have a significant effect on reduction of inefficiencies. On the other hand, the results of the systems analysis show a greater responsiveness of farmers to institutional and socio-economic factors than to market price factors. Thus, either the price factors or non-price factors or both can be used as policy levers to influence the expansion of dairy production in the marginal zones and in the country as a whole.

7.4 Overall Policy Implications and Recommendations

The results of this study have shown that farmers are quite responsive to market price factors. This can perhaps be attributed to the policy of liberalization which resulted in decontrol of prices in the dairy industry in 1993. However, much more can still be done within the liberalized market environment to influence prices and stimulate output supply. For example, there is need to ensure that the livestock manufacturing feed markets are efficient. Also, the government can lower the import duties on imported feed ingredients in an effort of making livestock feeds affordable to farmers. In addition to price decontrols, a further liberalization of the output markets would be expected to stimulate supply response. For example, removing the multiple indirect taxes on farmers' income would tend to increase milk prices. Also there is need to reduce the direct tax rate on farmer' profits, which stands at 16 percent.

The improvement of institutional and socio-economic setups needs public sector response. Judicious investments in physical and institutional infrastructure that has public good attributes should be undertaken in the marginal zones. Development of physical and institutional infrastructure in rural areas is self-reinforcing; it is necessary for reducing transaction and production cost inefficiencies, increasing access to production resources and markets by smallholder farmers. Ultimately, it enhances efficiency in input and output markets. However, it requires the enhancement of public expenditure on rural road infrastructure and its management, rural water supply, extension and credit services, farm records, animal feed storage systems as well as other agricultural support services. In summary, since farmers in a technically developing dynamic agriculture depend much more on use of purchased inputs, all the related farm support systems must also adjust continuously to new demands.

In sum, the area of public policy and management is the primary challenge facing Kenya if at all agricultural production is going to develop into prosperous economies in the rural marginal areas. The government remains the major player in promoting agricultural production and particularly the development of smallholder dairy even in a liberalized market economy. The policy interventions identified in this study require major public development expenditures. However, such expenditures should be viewed as part of the on going development strategy to alleviate poverty in the rural areas.

7.5 Areas for Future Research

Quite a number of issues in smallholder dairy production still need to be investigated. This study focused on the economic efficiency of dairy breeds, production structure and supply response in the marginal zones. However, a well developed dairy industry needs a properly established livestock feeds market for supply of inputs. Currently, there is lack of information on the size of the livestock manufacturing feeds industry, its operations, performance and in general a livestock feed industry policy in Kenya. Future studies can be directed in this area. Another area of interest would be an extension of the current study to determine the technical efficiency of the smallholder dairy farms. This kind of study would provide information on the technical relationships between inputs and output to farmers. In such a study, it would be advisable to target those farmers who are using manufactured feeds as a supplement or a complement. This would avoid the issue of many missing cases when establishing the emerging technology of dairy production in the marginal zones.

Another area of research would be to find out why some of the farmers would not want to be more efficient. This would require a follow up study to interview the same farmers and pin point their inefficiencies and enquire from them why they do not want to change. One possible reason would be that the dairy enterprise is inefficient, but the overall farm is efficient. Another possibility is that these farmers are actually efficient and also that there could be other identifiable variables influencing the enterprise but are not yet captured by the model.

There is need to study the effect of rural road infrastructure within the marginal zones in a regional perspective and determine the impacts of road net work on agriculture. This would involve putting into consideration the type of business activities in the region, agricultural sector enterprises, amount of traffic, the current amount of roads (in kilometres) and their types i.e. tarmac, weather road, earth road and the population of the people affected by the transportation and the road net work system. This might involve the use of a regional general equilibrium model e.g. Computable General Equilibrium (CGE).

In the marginal zones, there is relatively little research work done on dairy feeds and especially protein feed production and matching the various nutrient requirements for the dairy cows. There is therefore need for research programs on matching protein needs with the current roughage consumption.

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APPENDICES

Appendix A: Kernel Density Function Statistics

```
+---------------------------------------+
| Kernel Density Estimator for U        |
| Observations        =           255   |
| Points plotted      =           255   |
| Bandwidth           =       .103678   |
| Statistics for abscissa values----    |
| Mean                =       .453181   |
| Standard Deviation  =       .348939   |
| Minimum             =       .054573   |
| Maximum             =      2.703290   |
| ----------------------------------    |
| Kernel Function     =      Logistic   |
| Cross val. M.S.E.   =       .000000   |
| Results matrix      =        KERNEL   |
+---------------------------------------+
```

Appendix B: Computations of Marginal Effects

For the i-th firm in the t-th time period, cost efficiency is predicted using the conditional expectation:

$$CE_{it} = E[\exp(-u_{it}) \setminus E_{it} = e_{it}$$

$$= \{\exp(\mu_* + 0.5\sigma_*^2)\}\{\Phi[(\mu_* / \sigma_*) + \sigma_*]\}/\{\Phi(\mu_* / \sigma_*)\}$$

$$= A(B / C) = AD$$

where

$$\mu_* = (1-\gamma)z_{it}\delta + \gamma e_{it} ,$$

$$\sigma_*^2 = \gamma(1-\gamma)\sigma_s^2 ,$$

$$\sigma_s^2 = \sigma_u^2 + \sigma_v^2, \gamma = \sigma_u^2 / \sigma_s^2 \quad , \quad e_i = v_i - u_i$$

$$A = \{\exp(u_* + 0.5\sigma_*^2)\},$$

$$B = \{\Phi[(u_* / \sigma_* + \sigma_*]\},$$

$$C = \{\Phi[(u_* / \sigma_*]\},$$

and

$$D = \{\Phi[(\mu_* / \sigma_*) + \sigma_*]\}/\{\Phi(\mu_* / \sigma_*)\} .$$

We wish to obtain the partial derivative of the cost efficiency measure with respect to the j-th element of the z vector. Now, by the chain rule we have[8]:

$$\frac{\partial CE}{\partial z_j} = \frac{\partial CE}{\partial \mu_*}\frac{\partial \mu_*}{\partial z_j} . \qquad \textbf{(1)}$$

Furthermore we have:

8 From this point forward the firm and time subscripts are dropped

$$\frac{\partial \mu_*}{\partial z_j} = (1-\gamma)\delta_j, \qquad \textbf{(2)}$$

$$\frac{\partial C}{\partial \mu_*} = \frac{1}{\sigma_*}\phi(\mu_* / \sigma_*) = C',$$

$$\frac{\partial B}{\partial \mu_*} = \frac{1}{\sigma_*}\phi[(\mu_* / \sigma_*) + \sigma_*] = B',$$

$$\frac{\partial D}{\partial \mu_*} = \frac{CB' - BC'}{C^2} = D',$$

and

$$\frac{\partial A}{\partial \mu_*} = A.$$

Using these results we obtain:

$$\frac{\partial CE}{\partial \mu_*} = AD' + DA = A(D' + D)$$

$$= A\left\{\left[\frac{CB' - BC'}{C^2}\right] + \frac{B}{C}\right\}$$

$$= \frac{A}{C^2}(CB' - BC' + CB).$$

Thus, using this result and equations (1) and (2) we obtain:

$$\frac{\partial CE}{\partial z_j} = \frac{A}{C^2}(CB' - BC' + CB)(1-\gamma)\delta_j.$$