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Full Length Research Paper

Measurement of economic efficiency for smallholder dairy cattle in the marginal zones of Kenya

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Exotic dairy cattle have been adopted in the transitional zone IV of Kenya contrary to the opinion of experts who previously hypothesized that the "drier transitional zones" could not meet the requirements of the high performing exotic breeds. However, the economic efficiency of these breeds and the factors influencing them have not been ascertained and growers in the region are using these breeds. This study surveyed smallholder dairy farmers in the transitional zones of Machakos and Makueni Districts, and used a stochastic frontier translog cost function approach to determine their efficiency. The findings show that cost inefficiency ranges from 0.01 - 81.11, with a mean of 27.45%. Exotic dairy breeds are the most efficient in the transitional zones. Ayrshire achieved the lowest cost inefficiency (24.36%), followed by Friesians (25.08%) and Jersey (25.54%). Sahiwal (28.43%) has the lowest cost inefficiency among the indigenous breeds. The cooperative societies in the transitional zone IV were more efficient than those in the Upper Midland (UM) zone. Road infrastructure, extension and credit significantly reduce cost inefficiency. Keeping dairy records and primary level eight education are the key characteristics influencing efficiency. Policy and decision makers can use these institutional and socio-economic findings to inform education and policy aimed at improving efficiency of dairy production in the transitional zone IV in the medium potential regions.

Key words: Dairy breeds, transitional zone IV, cost inefficiency, institutional, socio-economic factors.

INTRODUCTION

Exotic dairy cattle were first introduced in Kenyan highlands from Europe by European settlers almost a century ago (Omore et al., 1999). They were then placed on wet and cool highland regions with temperate climate similar to European climate. 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 sub-division of large farms and expansion of smallholder herds (Thorpe et al., 2000). Currently, most of the Kenya's 3 million dairy cattle are kept in smallholder agricultural areas in the highland regions. The exotic breeds are the pure Friesian-Holstein, Ayrshire, Guernsey, Jersey and Crosses (Muriuki, 2002). In this paper, all the pure high grade and dairy crossbreds together are termed as improved dairy breeds (IDBs).

Agro-climatic factors have been identified as some of the key determinants of dairy development in Kenya. Such factors include altitude, duration and amount of rainfall, types of vegetation and soil patterns, which have been used as a basis to classify geographic regions according to agro-ecological zones (AEZ) (Jaetzold and Schmidt, 1983). The land use potential for crops and livestock for each region depends on AEZ distribution, with belts ranging from high-altitude, cool tropical alpines to low altitude, warm coastal lowlands. According to land productivity potential, the country can broadly be divided into three regions that is high, medium and low potential regions.

The high potential regions cover about 11% of the land surface in Kenya. Most of it has wet and cool temperate kind of climate which provides a suitable environment for water availability and production of dairy feeds throughout the ear. This region has Upper Highland (UH), Lower Highland (LH) and Upper Midland (UM) AEZs. The UH has annual rainfall of over 1200 mm and occasionally

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experiences frost. The altitude ranges from 2400 - 2500 masl. The Lower Highland Zone (LH) lies within an altitude range of 1800 - 2400 masl and is characterized by high rainfall of over 1000 mm per annum. The majority of Kenya`s pure dairy cattle are concentrated in this zone. Most of the UH and LH zones were formerly occupied by European settlers who introduced pure dairy grade cattle from Europe, sheep, wheat and pyrethrum farming. The third AEZ in this region is Upper Midland (UM) Zones I, II and III which is a warm and wet mid highland altitude region. It is characterized by annual rainfall ranging between 750 - 1,000 mm and can be as high as 2500 masl. Smallholder dairy is well established in this zone. It also has great potential for future dairy intensification and commercialization.

Land sizes in these traditional dairy keeping regions have been continuously declining due to intergenerational subdivision of farms driven by the rapid growth in population density (Republic of Kenya (RoK), 2001). Also, since the development of the smallholder dairy in high potential regions, there has not been a major technological advancement to enhance dairy productivity, which is needed for continued growth and development of the sub-sector (RoK, 1980). The scope for increasing dairy production in the country has been through horizontal expansion to the medium potential regions and dairy technology transfer and adoption in the coastal lowlands and Western Highlands.

The medium potential regions cover 9% of Kenya's land surface and consist of the transitional AEZ IV with a warm and dry climate. They are characterized by a bi-modal rainfall pattern with an annual mean ranging between 625 and 850 mm and an altitude of 1000 - 1900 masl. Most crop production is undertaken during the October - February short rain season which accounts for approximately 70% of the total annual agricultural production (RoK, 2002a). 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 and Huylenbroeck, 1999). Availability of water and animal feeds is seasonal due to erratic rainfall patterns.

The rest of the land mass (80%) is a low potential region with annual rainfall of less than 625 mm. It consists of semi-arid, arid and very arid agro-ecological zones. These are rangelands characterized by poor vegetation cover, fragile soils, high temperatures and frequent wind storms. Crop production is very limited but they support zebu cattle, sheep, goats and camels mainly kept by pastoral and nomadic tribes.

Since 1980s, farmers in the transitional zone IV have been adopting and keeping exotic dairy cattle through technology diffusion from the high potential regions. The expansion of exotic breeds into this AEZ zone is contrary to local wisdom that less productive but well acclimatized Zebu breeds are better dairy breeds to own in these regions. However, acclimatization of exotic dairy breeds and modification of the farm environment such as on- farm water supply, production of animal feeds and construction of feed storage structures (Trail and Gregory, 1981), have accustomed exotic breeds to the transitional zone IV. In addition, animal scientists have come up with upgraded crossbreds suitable for these areas. Currently, exotic breeds, which were considered alien to the transitional zone IV environments in the last two decades, are now available and smallholder farmers have formed dairy cooperative societies to enhance milk marketing (RoK, 1985 - 2003). Expectations are that as the country's population pressure on land increases, new growth in dairy production will be based on intensification and efficient production in the transitional lands coupled with some capital investments on the smallholder farms to transform these areas to zones of high value dairy production (Ngigi, 2005).

The current observed establishment of smallholder dairy in the transitional zones seems contrary to the earlier scientific thinking in Kenya. Dairy experts in 1970s hypothesized that the "drier transitional zone IV" could not meet the requirements of the high performing exotic breeds. They argued that improved zebu breeds with lower nutritive requirements and greater adaptability to marginal conditions, would be more suited to the transitional and semi-arid environments, even though their production response capability is relatively low (Kimenye and Russell, 1975). As a result, 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 con-straints. 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 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). It is argued that the potential performance of these larger breeds cannot be maximized under the small-scale management regime of the transitional zone IV in the medium potential regions. The smallholder farmers have often not followed the extension re-commendation given and have instead shown preference for high grade breeds as a key component of their improved milk production strategies (Bebe et al., 2003). Upgrading of indigenous zebu breeds has targeted improvement to higher exotic grades with disregard for the ecological and socio-economic characteristics of the production systems. Even though results from several dairy studies discourage the use of high grade breeds, the contrary has continued to be observed (Rege, 1998). Although considerable efforts have been directed at transfer, adoption and use of IDBs (Nicholson et al., 2004) little or no attention has been given to the relationships between efficiency of high grade dairy breeds, improved dairy herd

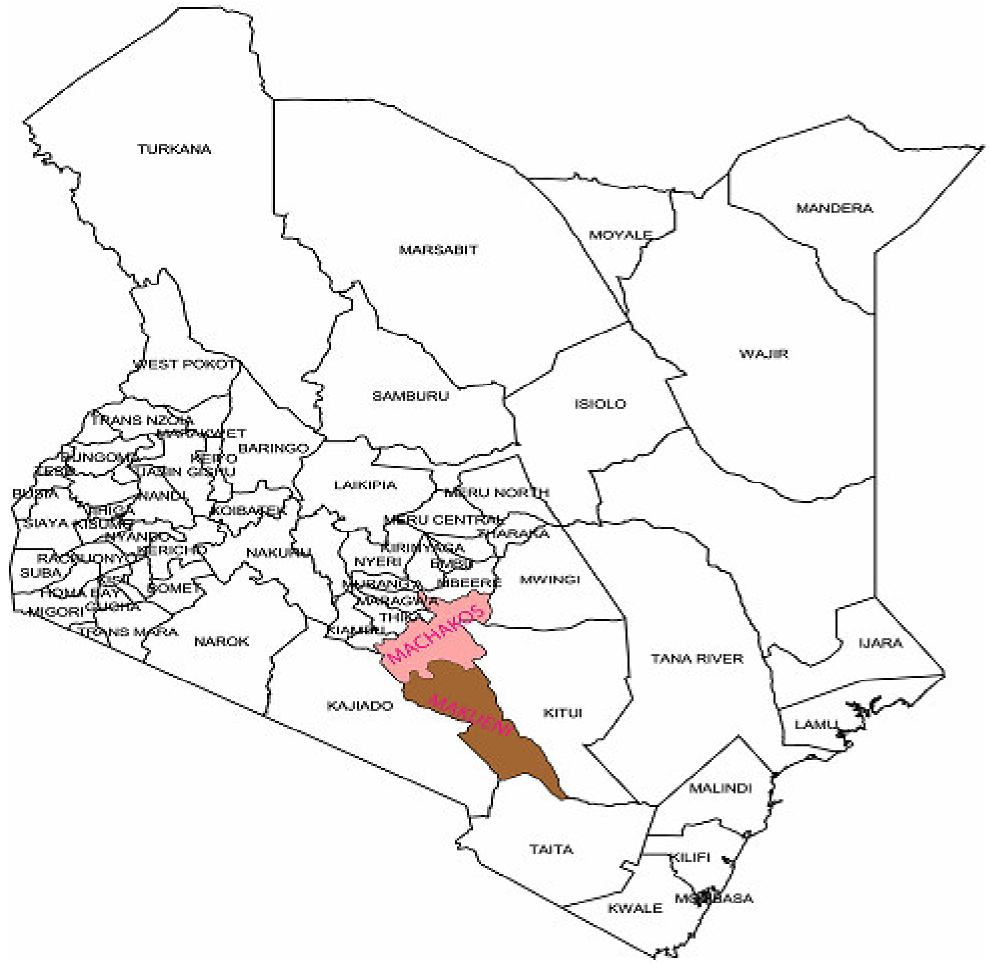

Figure 1. Location of Machakos and Makueni Districts in Kenya (Shaded).
Source: Survey of Kenya, 2007.

attributes, market indicators and household characteristics in the transitional zone IV. 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 transitional zones of Kenya. Therefore, the purpose of this paper is to determine the economic performance of the exotic dairy breeds for small land holders. To achieve the objective of the current study, the stochastic frontier framework approach is used.

IMPORTANCE OF SMALLHOLDER DAIRY IN THE STUDY AREA

This study was carried out in Machakos and Makueni Districts (Figure 1). They constitute the main transitional zone districts of Kenya with fairly established dairy production. The smallholder producers have organized themselves into small dairy cooperative societies for ease of milk marketing. Expectations are that the dairy production efficiency levels and marketing structures developed in Machakos and Makuenin can be emulated by the rest of the districts adopting exotic dairy cattle in the transitional zones. The establishment of smallholder dairy industry in this region has followed a slightly different path from that currently being used in the high potential regions and the coastal lowlands. Adoption of dairy in these districts has been as a result of a slow process of technology diffusion from high potential zones, with minimal public service involvement. However, in the rest of the regions, dairy production is being established through judicious means of technology transfer resulting from a joint effort of the government and development partners. Small scale dairy farmers in the transitional zone IV are often neglected in policy making and in the planning of extension and dairy development programs. For example, the Dairy Cattle Research Project 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 was established with an objective of disseminating dairy technology to small l- scale farmers mainly in the high potential zones where land is scarce and farm sizes small. It locked out dairy farmers in the transitional districts. Due to lack of national attention compared to the high potential regions, the constraints and the production potential of the transitional zone IV are rarely investigated and understood even by the professionals.

Agriculture provides employment to the majority of the people in the transitional zones (RoK, 2002b). However, it is unreliable and food deficits are often experienced. Crop farming is mainly for subsistence purposes. There are no established cash crops; like tea and coffee which are grown in high potential areas. There are also limited off-farm employment activities such as tourism and fishery industry, like in the coastal areas of Kenya. Household incomes in the transitional zone IV are therefore low (RoK, 2002a). The population census of 1999 shows that 73.1 and 63.3% of the population in Makueni and Machakos Districts respectively live below the poverty line[1] (RoK, 2000). Hence, reduction of poverty remains one of the greatest challenges.

The establishment of market oriented dairy production in the transitional lands of Kenya therefore cannot be overemphasised. Alternative new agricultural activities which offer higher returns to resources, offer 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 transitional zone IV. 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 dairy products in the township and urban areas. 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. Since 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).

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

RESEARCH METHODOLOGY

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 production frontier and cost function respectively. The cost function represents the dual approach in that technology is seen as a constant towards the optimizing behaviour of firms (Chambers, 1983). The cost function can be used to simultaneously predict both technical and allocative efficiency of a firm (Coelli, 1995). This study has adopted a stochastic cost frontier based on the Battese and Coelli (1995) model. This 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. The stochastic cost function is defined as:

$$C_i = f(y_i, w_i) + (v_i + u_i) \quad (1)$$

Where v_i values are assumed to be independently and identically distributed $N(0,\sigma^2_v)$ two sided random errors, independent of the u_i. u_i 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 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:

$$u_i = \delta z_i + W_i \quad (2)$$

Where z_i is a vector representing possible efficiency determinant, and δ is a vector of parameters to be estimated. W_i, the random are 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 conditioned on the level of the farm output. This measure has a minimum value of one. Cost inefficiency can therefore be defined as the amount by which the level of production cost index for the firm is greater than the firm cost frontier. For example, an actual cost index of 1.25 where the frontier value is 1 would have a CI index of 0.25. An estimated measure of cost inefficiency index for dairy farm i is:

$$CI_i = \exp(-u_i) \quad (3)$$

Econometric specification and estimation 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). 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:

$$\ln C_i = \alpha + \alpha_q \ln Q_i + \sum_i^n \alpha_i \ln P_i + \frac{1}{2}\beta_{qq}(\ln Q_i)^2 + \frac{1}{2}\sum_i^n \beta_i \ln P_i \ln P_i + \sum_i^n \beta_{ij} \ln P_i \ln P_j$$
$$+ \sum_{i=1}^n \beta_{qi} \ln Q_i \ln P_i + \gamma_m \ln Z_m + \frac{1}{2}\gamma_{mm}(\ln Z_m)^2 + \sum_{mi}^n \gamma_{mi} \ln Z_m \ln P_i + \sum_{mq}^n \gamma_{mq} \ln Z_m \ln Q_i + e_i \quad (4)$$

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

The inefficiency model (u_i) is defined as:

$$u_i = \delta_0 + \sum_{d=1}^n \delta_d W_d + \omega \quad (5)$$

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), 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. The estimation procedure 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 4 with the behavioural inefficiency model, Equation 5 estimated in one step maximum likelihood estimation (MLE) using LIMDEP programme (Greene, 2002).

Data sources and collection

The primary data for the study pertains to a farm-survey of smallholder dairy producers conducted during June - September, 2006 in five dairy cooperative societies. A questionnaire instrument was used for data collection. The information gathered included both quantitative and qualitative forms of data. A two stage random sampling strategy was adopted. First a random sample of five of six dairy societies was undertaken. A list of all members and their registration numbers was ascertained. Then, a proportionate sample of active dairy farmers was randomly selected for the study (Table 1). The survey data collected was used to create the appropriate variables for the analysis. The descriptive statistics for the survey data are presented in Table 2.

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. The GPS map was used to measure the distances of the farms to the various dairy utility services and road infrastructure. Table 3 shows the descriptive statistics of road infrastructure distances with respect to the surveyed dairy households.

Data and variable definitions

The variables used in cost efficiency analysis were created from the survey data collected. The dependent variable is the natural logarithm of the total variable costs (LNCOST) of milk production. The total variable cost is a sum of expenditures for concentrates, mineral salts, milking serve, hay, locally purchased feeds, 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. 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 calculating the total annual expenditure of both family and hired labour on dairy cattle and the total number of person hours. 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) and area of dairy cattle grazing (LNACRE).

Several variables were hypothesised as being responsible for the estimated farm-specific cost inefficiencies (Table 4). On an a *priori* basis, age, education level and years of experience 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 de-crease efficiency. However, no a *priori* expectation could be increase efficiency. The distance from the farm to the watering point is placed on off-farm employment. Engagement in off-farm income generating activities can reduce the amount of labour available for on-farm production. Nevertheless, off-farm incomes 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

Table 1. Number of dairy farmers selected for the study.

Items	Dairy cooperatives in Machakos district		Dairy cooperatives inMakueni 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 transitional zone IV of Kenya, June-September, 2006.

Table 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

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 zone IV which is relatively hot and dry. Therefore, keeping dairy cows in AEZ VI is expected to reduce

Table 2. Contd.

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
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 transitional zone IV of Kenya, June - September, 2006.

Table 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 transitional zone IV of Kenya, June - September, 2006.

Table 4. 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

efficiency.

MODEL ESTIMATION AND RESULTS

Table 5 shows results of the stochastic frontier final models for Translog and Cobb-Douglas functional forms, after the data was transformed to take care of heteroscedasticity, high correlation and to ensure orthogonality condition. Most of the independent variables in the stochastic frontier model have the expected signs and are significant. However, the milk output value variable has a negative sign. 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. A plausible reason for this result is that observed costs of production from agricultural enterprise budgets in Kenya, have been increasing (Nyoro, 2002) due to increasing input costs; whereas yields are either stagnant or decreasing (Nyoro, 2002). For example, the observed input costs particularly fertilizer has increased from Kshs 1250 per 50 kg bag in 1998 to Kshs 2200 per 50 kg bag whereas yields of maize have declined from 1.85 metric tonnes per hectare in the period 1990 to the current yield of 1.57 metric tonnes per hectare (Kibaara, 2005). The observed average smallholder milk yield in the high

Table 5. Translog and Cobb-Douglas cost functional forms of stochastic frontier.

Variable name	Variable label	Parameters	Translog model	Cobb-Douglas model
			Stochastic frontier	
LNQNT	Constant	Bo	6.8806***	30.6632***
LNFDP	Milk output	β1	-0.1692***	-0.0032
LNHELP	Feed price	β2	0.0003	0.0006
LNWAGE	Health price	β3	0.2968***	0.0079
SQQNT	Wage	β4	1.2598***	0.0069***
SQFD	Milk output* milk output	β5	0.0308***	
SQHEL	Feed price*Feed price	β6	0.0049	
SQWAGE	Health price *Health price	β7	0.0011	
QNTFDC	Wage * Wage	β8	-1.5289***	
QNTHELC	Milk output*feed price	β9	0.0095	
QNTWAGC	Milk output*health price	β10	0.0146	
FDHELC	Milk output* Wage	β11	0.2569***	
FDWAGC	Feed price*health price	β12	0.0034	
HELWAGC	Feed price *wage	β13	-0.0463*	
QNTPRDC	Health price*Wage	β14	0.0418*	
QNTACRC	Milk output*Produced feed	β15	-0.0810***	
FDPRDC	Milk output* Grazing acres	β16	-0.0606***	
FDACRE	Feed price* produced feed	β17	-0.0005	
HELPRDC	Feed price* Grazing acres	β18	0.0099	
HELACRC	Health price* produced feed	β19	0.0044	
WAGPRDC	Health price* Grazing acres	β20	-0.0012	
WAGACRC	Wage* produced feed	β21	0.0756*	
LNPRDFD	Wage* Grazing acres	β22	-0.0810	
LNACRE	Produced feed	β23	0.7114***	-0.0023***
SQPRDFD	Grazing acres	β24	0.7977***	-0.0018
SQACRE	Produced feed* Produced feed	β25	-1.3917***	
PRDACRC	Grazing acres* Grazing acres	β26	0.0438***	
LNQNT	Produced feed* Grazing acres	β27	0.6820***	
		Inefficiency model		
Constant	Constant	δ0	6.8463**	4.2005*
AGE	Age of manager	δ1	0.0178*	0.0134*
SCHED	Years of school	δ2	0.1154**	0.1337**
SQYRED	Years of school* Years of School	δ3	-0.0087**	-0.0087**
EXPER	Dairy experience	δ4	-0.0008	-0.0006
EXNTV	Number of extension visits	δ5	-0.0130*	-0.0214***
NUMCOW	Number of milk cows	δ6	-0.0058	-0.0146
RECODS	Dairy records	δ7	-0.4116**	-0.6570***
FDSTO	Feed storage	δ8	-0.4799	-0.3063
H20DS	Distance to water point	δ9	-0.0157	0.0201
CREDIT	Used credit	δ10	-0.4251**	-0.3693**
OFARM	Off-farm employment	δ11	0.1924	0.0562
WLKMODR	Walking distance to tarmac ratio	δ12	0.6002**	0.4621**
AEZ	Agro-ecological zone	δ13	-1.2248***	-0.9888***
		Variance parameters		
Lambda	Lambda = σ_u / σ_v	λ	3.6999***	2.0809***

Table 5. Contd.

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: Sample Survey of Dairy Households in the Transitional zone IV of Kenya, June-September, 2006.
*Significant at 10% level ($p < 0.10$); **Significant at 5% level ($p < 0.05$); ***Significant at 1% level ($p < 0.001$).

potential zones is 1923 litres per cow per year (Kilungo, 1999) and 1425 litres per cow per year (Kavoi, 2007) in the transitional zone IV, compared to the expected yield of 4000 L per cow per year. On the other hand, agricultural input quantum index for manufactured animal feeds increased from 161.5 in 2003 - 196.3 in 2007 (RoK, 2008). The respective price index for manufactured feeds increased from 83.1 - 142.9 in the same period. The increase in agricultural input prices coupled with declining agricultural output prices has resulted in overall worsening of agricultural terms of trade which declined from 92.5 in 2003 - 74.3 in 2007 (RoK, 2008). Overall, it is observed that the cost of food commodities are high relative to output values because of low yields, high input prices, declining agricultural output 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). It is possible that this scenario is now being captured by the various studies undertaken in Kenya in the recent past (Karanja, 2002; Kavoi, 2007). In this study, the mean cost efficiency is computed for each model. The estimated mean cost inefficiency is 27% for translog model and 12% for Cobb-Douglas model. The results and discussions focus on the translog cost function because of its flexibility as compared to the restrictive Cobb-Douglas functional form. For the translog model, γ is estimated at 0.9319 which can be interpreted that over 93% of random variation in the model is explained by inefficiency; implying a high level of inefficiencies exist in dairy farming.

Likelihood ratio tests were performed to test various null hypotheses as listed in Table 6. 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: $\beta_{ik} = 0$ is rejected at 1 per cent in favor of the translog production function. The second hypothesis specifies that the inefficiency effects are all together absent from the model that is H_0: $\gamma = \delta 0 = \ldots = \delta 13 = 0$. 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 that is $\gamma = 0$. 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 that is 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.

The CI of the ith farm is calculated from the following equation:

$CI_i = \exp(u_i)*100.$

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 7 from the translog cost function.

Figure 2 shows the distribution of cost inefficiency (CI) of dairy farms. The minimum estimated cost inefficiency is 0.0113%, the maximum is 81.1137% and the Mean is 27.4501%. The observation of wide variation in cost inefficiency is similar to the results from similar studies (Parikh et al., 1995; Karanja, 2002). Despite the wide variation in efficiency in this study, about 51% of the farmers seem to be skewed towards a cost inefficiency level of 25% and below (Figure 2). The implication of

Table 6. 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: sample survey of dairy households in the transitional zone IV of Kenya, June - September, 2006.

Table 7. Range of cost inefficiency by breed.

Range of CI percernt	Friesian	Ayrshire	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: Sample survey of dairy households in the transitional zone IV of Kenya, June-September, 2006.

these results is that in the short run, there is a scope to reduce dairy production costs by 27%.

It can be recalled that the use of exotic breeds and /or upgrading to exotic grades is generally discouraged in the transitional zone IV 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 7 shows that 50 percent of farmers keeping Friesian, 50% Ayrshire, 37% Guernsey, 33% jersey and 47% Sahiwal operate at or below 20% mean cost inefficiency. The large exotic breeds that are Friesian and Ayrshire have the largest percentage of farms with the lowest costs, followed by Sahiwal. Over 50% of farms with small size exotic breeds that is Guernsey and Jersey operate between 20 - 39 cost inefficiency. The majority of Boran farms operate at 40 - 59%, zebu farms 20 - 39% and zebu crosses operate at 40 - 59%. These results seem to reveal that the large exotic breeds and Sahiwal experience lower operational costs inefficiencies than the other breeds. To determine the breed with the lowest cost inefficiency, 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 Table 8. The results show that Ayrshire has the lowest cost inefficiency of 24.36% followed by Friesians with CI of 25.08%, Jersey 25.54% and Guernsey 30.17%. The indigenous breeds were lead by Sahiwal with 28.43%, Zebu upgrades 35.06%, Pure Zebu 36.46%, and Boran 50.31% 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% followed by Jersey keepers with 116.59%. 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%.

The Agro-Ecological Zones (AEZ) of the study area is characterized by hilly land pouches with Upper Midland (UM) AEZ II and III and transitional zone IV where smallholder dairy cattle are kept. Consequently, the study estimated cost reduction and profit increase of milk cooperative societies by AEZ and CI ranges as presented in Table 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 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 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%, followed by Masii with 19.38% and Makueni with 34.96%. The overall

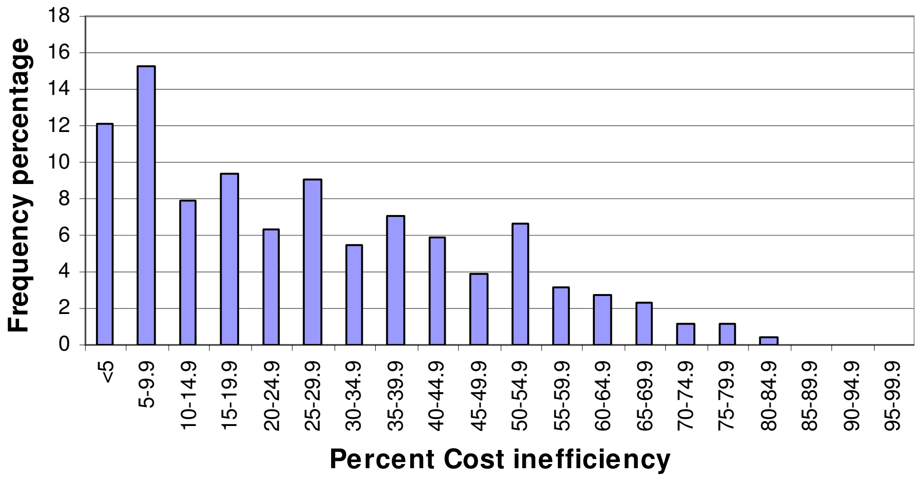

Figure 2. Frequency distribution of predicted cost inefficiency.

Table 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
	<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
Frisian	60 - 79	8.11	67.11	13654.76	92.42
	80 - 99				
	Overall mean	100.00	25.08	9280.94	56.65
	<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
Ayrshire	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

Table 8. Contd.

	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
Breed	**CI category**	**Percent of farms**	**CI percent**	**Cost reduction (Kshs)**	**Percent profit increase**
	<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
Zebu cross	60 - 79				
	80 - 99	6.67	81.11	15999.68	180.87
	Overall mean	100.00	35.06	9457.35	70.01
	<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
All breeds	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: Sample survey of dairy households in the transitional zone IV of Kenya, June - September, 2006.

inefficiency for all the farms is 27.45%.

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% in Kilungu, 98.36% in Mbooni, 63.78% in Masii, 62.15% in Wamunyu and 44.50% in Makueni, respectively. The overall profit increase is expected to be 76.72% if the factors causing inefficiencies are addressed.

EFFECTS OF SOCIO-ECONOMIC AND INSTITUTIONAL FACTORS ON COST INEFFICIENCY

Given the difference in cost inefficiency levels among dairy production units, it is appropriate to question why some producers can achieve relatively high efficiency whilst others are economically less efficient. The inefficiency model results are presented in Table 10. A negative sign on a parameter means that the variable decreases inefficiency, while a positive sign increases inefficiency. The results reveal that the age variable of the dairy manager is positive and significantly increases inefficiency in smallholder dairy. This implies that as the age of manager increases, inefficiency increases as well. The variable on experience was negative but insignificant.

The positive sign on years of school variable indicates that an increase in the number of school years increases cost inefficiency. This relationship is significant at 5% level. This finding is consistent with results from other cost inefficiency studies in Kenya (Karanja, 2002). However, the coefficient of squared years of schooling

Table 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
Macon	<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

variable in this study has a negative sign and is significant at 5% level. Studies on the effect of the number of school years on efficiency in some of the third world countries e. g. Kenya and Bangladeshi seem contrary to expectations. For example, Bravo-Ureta and Pinheiro (1993) and Philips (1994) showed that higher education improves efficiency in most of the developing countries. However in Kenya it has been shown that as the average number of years of schooling increases, inefficiency increases (Karanja, 2002; Kibaara, 2005). This could probably be explained by the observations that high education attenuates the desire for farming and the farmers tend to concentrate more on salaried employment. A similar observation is made in the current study. As the number of school years increases, inefficiency increases and the number of farmers decreases. Overall, full primary schooling of eight years seems to reduce cost inefficiency in dairy production to the first quintile.

The number of dairy cows kept variable is negative which implies that the variable tends to reduce inefficiency (Table 5). Thus as the number of cows increase, cost inefficiency decreases. However, this relationship is not statistically significant probably

Table 10. 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: Sample survey of dairy households in the transitional zone IV of Kenya, June - September, 2006.
(.) Means the figure is negative.

because the heard size of the milking cows is not yet optimal. Statistical results on categorizing the number of milking animals versus cost inefficiency quintiles indicated that the most efficient farmers have 4 cows. This finding is consistent with a study on cost inefficiency for coffee farmers in the central 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%. Table 5 shows that as the percentage of farmers who keep records increases, inefficiency decreases.

The institutional factors considered in this study are credit, distance to water point, extension visits, infrastructure and the Agro-ecological zone. The coefficient of the credit use variable is negative and significant at 10% level. This implies that credit use significantly reduces inefficiency. The coefficient on the distance to the water point variable is negative but is statistically insignificant.

Statistical results of quintiles versus distance to the water point showed that most efficient farms have the shortest distance to the point of watering dairy cows. 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.

The road infrastructure index variable was positive and significant at 5% level. This result implies that the walking distance to the tarmac road poses drudgery to the operations of dairy activities. The farmers walk long distances to the tarmac when delivering milk to the cooperatives. The dairy inputs from the market are carried manually for the whole distance to the homestead. Also, the livestock health officers and extension workers walk relatively long distances carrying their treatment kit manually when conducting their treatment rounds for animals among households. The speed of undertaking these activities is slowed down by the status of the road infrastructure. Road infrastructure is one of the institutional factors which might require some public action in an effort to expand dairy production in the transitional zone IV.

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 transitional zone IV are less inefficient and closer to their minimum cost frontier than the farmers in the cool and wet hilly zones. This result seems contrary to expectations because exotic dairy cattle usually perform better in the cool and wet hilly regions. Nevertheless, this finding is an indication that transitional zone IV reduce cost inefficiencies of exotic dairy cows and perform better than the cool and wet hilly regions.

Marginal effects

The estimated parameters on the variables of the inefficiency model presented in Table 5 tell us little about the magnitude of the effect of changes on cost inefficiency. To address this shortcoming, the marginal effects associated with the thirteen *z*-variables evaluated at their sample means (Frame and Coelli, 2001) are listed in Table 10. The results of marginal effects show the amount by which cost inefficiency increases if the variable is increased by one unit. For example one year of age would increase cost inefficiency by 0.0053 (that is 0.53%), which results in increase in average cost by Kshs 47.72. 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 used credit realized a cost reduction of Kshs. 1140.00. A 1% increase in the ratio of walking distance from homestead to the tarmac road results in 18% increase in average cost inefficiency that is, cost of production increases by Kshs. 1606.00 on average. Finally, farmers in the lowland marginal areas are 30% less cost inefficient compared to farmers in the cool and wet hilly zones. This is equivalent to a reduction of costs by Kshs. 2786.00 on average in the transitional zone IV.

Recommendations and policy implications

The results of this study clearly reveal that exotic breeds are the most efficient in the medium potential regions. Ayrshire breed achieved the lowest cost inefficiency (24.36%), Friesians (25.08%) and Jersey (25.54%). Sahiwal has the lowest CI (28.43%) among the indigenous breeds. The cooperative societies in the transitional zone IV that is Wamunyu (19.31%), Masii (19.38%) and Makueni (34.96%) are more efficient than those in Upper Midland (UM) II and III. The overall inefficiency for all the farms is 27.45%.

The results of this study have further concluded that one of the key avenues for increasing efficiency is to address the institutional and socioeconomic infra-structure which causes drudgery in dairy operations.

These conclusions have led us to identify a number of policy issues that are recommended for attention. Road infrastructure is one of the factors influencing cost reduction significantly. The distance walked from the homestead to the tarmac road causes drudgery to dairy operations. This finding underscores the importance of providing adequate road net work to reduce the drudgery of transportation. Poor infrastructure hinders rural development because it impacts agricultural productivity negatively. It also increases transportation costs for inputs and the produce thereby reducing the margins to farmers. New investments and improvements of the existing road net work would require the enhancement of public expenditure on rural infrastructure. This implies that the government remains the main player in rural road development in order to promote smallholder agriculture.

A regional transportation systems analysis would be necessary to investigate the type of the required road net work, the business activities and the population affected by the rural road infrastructure.

The number of extension visits significantly reduces cost inefficiency. It is therefore prudent that farmers have access to extension services. There is need also to prioritise keeping of dairy records as part of the extension service work. The extension service used to train and visit farmers on their farms before the liberalization of the industry in 1993. However, after liberalization, farmers in demand of extension services have to seek for 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 transitional zone IV. 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. Farmers dependent on public extension services in the transitional zone IV because there is virtually no private sector participation unlike in animal health. Therefore, improvement of extension services as well as other support services that have a “public good component” requires the enhancement of public expenditure. Perhaps a strategy of joint extension service provision between the government and the cooperative societies can ameliorate this situation in the short run.

However, in the long run, the cooperative societies can employ extension staff and veterinary doctors as part of their human resource establishment.

This study has shown that use of credit reduces cost inefficiency. However, the main deterrent to borrowing credit by farmers is high interest rates since the annual rate ranges between 12 - 65% for commercial banks and village banks, respectively (Kodhek, 2004). Wamunyu and Masii cooperatives offer farmers feed credit and the debt is recovered from the monthly milk deliveries. Coincidentally, it is only in these two where farmers have the lowest cost inefficiency. This finding underscores the importance of providing affordable credit to farmers.

In the early 1960s, the private commercial banks were required by law to disburse 17% of loans to agriculture (Kodhek, 2004). Currently, agricultural lending by commercial banks stands at 5.35% of the total lending portfolio. Therefore, it is prudent to put in place dis-cretionary policy measures aimed at improving smallholder farmers’ access to credit at affordable rates in order to boost dairy productivity and efficiency.

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