

## ESTIMATION OF MILK PRODUCTION EFFICIENCY OF DAIRY COW FARMS IN EMBU AND MERU COUNTIES OF KENYA

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### Abstract

This study aimed at determining the technical and cost efficiencies of dairy cow farms in Embu and Meru counties of Kenya, as indicators of milk access potential. Data were collected from 135 randomly sampled farms in 2010. The sample size was determined using the Cochran's (1977) formula. Data were collected using semi-structured questionnaires, after which they were entered into the excel spreadsheets and edited. Stochastic frontier production and cost functions were estimated using the maximum likelihood estimation (MLE) technique. Results revealed that the number of lactating cows and the amounts of roughages, concentrates, and mineral supplements were the major factors influencing milk output, while the prices of roughages and labour caused most variation in the production cost. The mean farmers' technical and cost efficiency indices were 0.837 and 1.044, respectively. The function coefficient of the production model was 2.11. These results implied that milk production could be increased by 16.3% through better use of available resources given the current state of technology without extra cost, while the cost of milk production could be decreased by about 4.4% without decreasing output. It was concluded that optimization of farm efficiencies while taking advantage of economies of scale through increased production inputs could be part of short-term measures to address the challenges facing smallholder dairy farming. The researchers require identifying inefficiency determinants and ensuring stakeholder involvement in the process to enhance adoption of the outputs. The policy makers should discourage sub-division of agricultural land while concurrently promoting enterprise specialization, support approaches to make feed concentrates, mineral supplements and chaff-cutters affordable, and emphasize on the reduction in cost of production.

**Key words:** stochastic frontier, cost and technical efficiency, function coefficient, roughages

### 1.0 Introduction

Kenya's dairy sub-sector spans about a century and ranks among the largest in sub-Saharan Africa (Ngigi, 2002). It accounts for about 3.5% of the National GDP and contributes to the livelihoods of about four million Kenyans through food, income and employment (Omiti *et al*, 2006). Various indicators however, show that the sector's performance is much lower than its potential. Per cow milk yield has invariably remained at an average of 6 kg over the last 30 years (MoLD, 2010), though it has a potential of more than 15. The country's per capita milk consumption is about 76.7 kg, while the WHO's recommendation is 200 kg (FAO, 2007). Kenya's milk enjoys preferential access to markets in the Eastern African region, but total export quantities are negligible (MoLD, 2010). The Country's milk is further shown to be expensively produced making it unaffordable. The country faces the risk of losing the local and regional market to more affordable imported products owing to the liberalization of world trade and the opening up of markets to international competition.

Various studies on dairy farming have been carried out to understand the status of milk production and marketing in Kenya, with a view to increasing the capacity to tap into the existing market opportunities. The study areas covered include: farmers' adoption of production technologies (Makokha *et al*, 2007); nutrition (Ongadi, 2006); farm-level milk production (Baltenweck, 2006; Gamba, 2006; Kimenju and Tschlerley, 2008); smallholder dairy profitability (Omiti *et al*, 2006); genetics (Kahi, 2004); production systems (Bebe, 2003); and milk production and marketing (Ngigi, 2002; Karanja, 2003 and Staal *et al*, 2008). Despite their many recommendations, the average milk yield per cow has not improved and per unit reduction in cost of production has yet to occur.

The present paper estimates the efficiency (technical and cost) of dairy cow farms in Embu and Meru Counties of Kenya. According to Kumbhakar and Lovell (2000) efficiency represents the degree of success which producers achieve in allocating the available inputs and the outputs they produce, in order to achieve their

goals. Producers are hardly fully productively efficient. The difference can be explained in terms of allocative and technical inefficiencies, as well as a range of unforeseen exogenous shocks (Reifschneider and Stevenson, 1991). Efficiency estimation provides an indication of the percentage by which potential output could be increased, or potential cost decreased, in relation to the corresponding production frontier (Kokkinou and Geo, 2009).

Farrell (1957) provided a measurement application on U.S. agriculture and was the first to measure productive efficiency empirically. His study on efficiency measurement led to the development of several approaches to efficiency and productivity analysis. These approaches include: the stochastic frontier production (Aigner *et al*, 1977; Meeusen and van den Broeck, 1977), distribution free approach (DFA) and the thick frontier approach (TFA) (all parametric), and Data Envelopment Analysis (DEA) (Charnes *et al*, 1978) and the free disposal hull (FDH), (both non-parametric).

In parametric approaches, a functional form is assumed and econometric methods are used to estimate it. A functional form is imposed on the production function and assumptions about the data are made (Chirwa, 2007). The production function estimation is mostly performed by employment of stochastic frontier analysis (SFA), which accounts for both inefficiency and random noise effects.

**2.0 Materials and Methods**

**2.1 Description of Study Area, Sampling Technique, Sources of Data and Method of Collection**

Embu and Meru Counties lie on the Eastern Central highlands of Kenya. Embu County is at 0030° S, 3730°E and Meru at 0°, 38 00° E. They cover an area of 2826.4 and 6924 km<sup>2</sup>, respectively. They have two rain seasons; March to May and October to December. Their annual rainfall totals range in-between 600-2200 and 500-2600mm, respectively. The temperature ranges for the respective counties are; 12-27 and 11.4-28°C (Jaetzold *et al*, 2006).The two counties border Mt. Kenya and the region is ideal for dairy farming. Their human populations according to the 2009 census data were 516,212 and 1,356,301, respectively (RoK, 2009).

The sample for this study was drawn from Embu East and Igembe South districts within the Embu and Meru counties, respectively. A descriptive survey technique using semi-structured questionnaires was used in data collection, with respondents sampled randomly. The following were recorded as data:total herd size (counted); milking herd size (counted as the total number of lactating cows); breed (observed and compared to photo card); roughages (kg) (amount per cow per day); average amount of concentrate (kg) (ascertained by re-weighing the amount in a vessel used by the farmer in feeding a cow per day); average amount of mineral supplements (kg) (obtained from farmer’s response); average number of labour hours spent on herd per day (hours) (average time taken on dairy farming activities in a day by either a family member or hired or both); land size owned (acres) (obtained from the farmer’s response) and chaff-cutter ownership (presence or absence of chaff-cutter in a farm, obtained by observation and/farmer response). Data on milk output per cow was collected. Further data were on the cost of roughage, concentrate, mineral supplements and labour per day. Secondary data were collected from reports and other literature obtained from the Ministries of Livestock Development, Agriculture and the Ministry of State for Planning, National Development and Vision 2030.

**2.2 Stochastic Frontier Production and Cost Functions**

The stochastic frontier production function has two error terms one to account for random effects (e.g., measurement errors in the output variable, weather conditions, diseases, etc. and the combined effects of unobserved/uncontrollable inputs on production) and another to account for technical inefficiency in production. The stochastic frontier production function can be written as;

$$Y_i = f(x_i; \beta) + \varepsilon_i \quad \text{where, } i=1, 2, \dots, N \dots\dots\dots(1)$$

$$\varepsilon_i = v_i - u_i \dots\dots\dots(2)$$

where,  $Y_i$  represents the output level of the  $i^{\text{th}}$  farm;  $f(x_i; \beta)$  is a suitable function (such as Cobb-Douglas or translog production functions) of vector,  $x_i$ , of inputs for the  $i^{\text{th}}$  farm and a vector,  $\beta$ , of unknown parameters.  $\varepsilon_i$  is an error term made up of two components:  $v_i$  is a random error having zero mean,  $N(0; \sigma_v^2)$  which is associated with random factors such as measurement errors in production and weather which the farmer does not have control over. It is assumed to be independent of  $u_i$ . On the other hand,  $u_i$  is a non-negative random variable representing the inefficiency, which is assumed to be distributed independently and obtained by truncation at zero of the  $N(\mu_i, \sigma_u^2)$  distribution.

## 2.3 Empirical Models

### 2.3.1 Empirical Model for Technical Efficiency Estimation

In this paper, the Cobb-Douglas functional form was assumed in specifying the production function. The functional form was used because it is easy to estimate and allows the focus to be on the error term (Kumbhakar and Lovell, 2000). It is easy to interpret and has relatively few parameters compared with other specifications. The maximum likelihood estimates of the parameters of the production function were estimated using the procedure in the FRONTIER 4.1c (Coelli, 1996) econometric software. The function was specified as;

$$\ln Y_i = \beta_0 + \beta_1 \ln X_{1ij} + \beta_2 \ln X_{2ij} + \beta_3 \ln X_{3ij} + \beta_4 \ln X_{4ij} + \beta_5 \ln X_{5ij} + \beta_6 \ln X_{6ij} + \beta_7 \ln X_{7ij} + \beta_8 \ln X_{8ij} + \beta_9 \ln X_{9ij} + v_{ij} - u_{ij} \dots \dots \dots (3)$$

where;

$\ln$  represents logarithm to base e; subscripts  $ij$  refers to the  $j$ th observation of the  $i$ th farm;  $Y$  is the total milk output by a farmer in kilograms;  $X_1$  represents the total herd size owned;  $X_2$  is the milking herd size;  $X_3$  represents the cow breed;  $X_4$  represents the amount of roughages to the herd per day (Kg);  $X_5$  is the average amount of concentrate feed per farm per day (Kg);  $X_6$  represents the average quantity of mineral supplements per herd per month (Kg);  $X_7$  is the average number of labour hours per herd per day (Hours); and  $X_8$  represents the size of land owned (Acres); and  $X_9$  represents the presence or absence of chaff-cutter technology in the dairy farm.

### 2.3.2 Empirical Model for Cost Efficiency Estimation

The translog function was used to specify the stochastic cost function because it allows the data to drive the shape of the cost function with few restrictions. Under the translog specification, the one-sided error component  $u_i$  captures both input oriented technical and allocative inefficiency (Nadolnyak *et al*, 2000; as cited in Lucila *et al*, 2005). The model was specified as shown below and estimated using FRONTIER 4.1c program (Coelli, 1996):

$$\ln (TC/cfeed) = \beta_0 + \beta_y \ln \text{output} + \sum_{j \neq y} \beta_j \ln (p_j/cfeed) + \frac{1}{2} \beta_{yy} (\ln \text{output})^2 + \frac{1}{2} \sum_j \sum_{h \neq j} \beta_{jh} \ln (p_j/cfeed) * \ln (p_h/cfeed) + \sum_{j \neq y} \beta_{jy} \ln \text{output} * \ln (p_j/cfeed) + v_i + u_i, \dots \dots \dots (4)$$

where;  $TC$  is the actual total cost of production;  $cfeed$  is average price of concentrate feed per day;  $v_i$  represents the deviation from the frontier due to random events;  $u_i$  represents inefficiency;  $\beta$  is a vector of unknown parameters, and;  $p_j$  is the unit cost of input. After normalizing the total cost and the input prices by the price of concentrate feed and expressing all the variables in logarithms, the estimating equation became:

$$tcost = \beta_0 + \beta_1 \text{outpt} + \beta_2 rfeed + \beta_3 \text{minsuppls} + \beta_4 \text{labr} + \frac{1}{2} \beta_5 \text{outpt}^2 + \frac{1}{2} \beta_6 rfeed^2 + \frac{1}{2} \beta_7 \text{minsuppls}^2 + \frac{1}{2} \beta_8 \text{labr}^2 + \beta_9 \text{outptrfeed} + \beta_{10} \text{outptminsuppls} + \beta_{11} \text{outptlabr} + \beta_{12} rfeedmin + \beta_{13} rfeedlabr + \beta_{14} \text{minsuppls}labr + v_i + u_i, \dots \dots \dots (5)$$

where,  $tcost$ = total cost of production (Ksh);  $outpt$ = total farm milk output/day (Kg);  $minsuppls$ = total price of mineral supplements to the herd/day (Ksh);  $labr$ = average cost of labor per day (Ksh);  $outpt^2$  = output x output;  $rfeed^2$  = roughage feed x roughage feed (kg);  $minsuppls^2$  = mineral supplements x mineral supplements (kg);  $labr^2$  = labour x labour (Hr);  $outptrfeed$ = output x roughage feed;  $outptminsuppls$ = output x mineral supplements;  $outptlabr$ = output x labour;  $rfeedmin$ = roughage feed x mineral supplements;  $rfeedlabr$ = roughage feed x labour;  $minsuppls$ labr= mineral supplements x labour.

## 3.0 Results

Below is a summary of the descriptive statistics (Table 1), later used in the stochastic production and cost function models.

Table 1: A summary of descriptive statistics of select study variables

	Embu East(n=96)	Igembe South (n=39)	Overall (n=135)
Average herd Size	3.89	4.03	3.93
Milking herd size	-	-	1.56 cows-lactating
Breed	-	-	89%; Friesian, Ayrshire & their crosses
Roughage feeds fed (kg)	51.9 (11.6 <sup>a</sup> )	52.8 (11.4)	Average; 52.2 (11.7)
Concentrate feeds (kg)	2.2 (1.2)	2.1 (1.4)	Average; 2.2 (1.8)
Mineral supplements (kg)	4.2 (3.3)	4.5 (4.0)	Average; 1.1 (3.5)
			cow/day
			cow/month

Labour time (Hrs)/ cow/day	2.1	2.66	2.2
Land size/farm	-	-	Average of 2 acres
Chaff-cutter ownership	-	-	23.7% own chaff-cutters
Per Cow Yield (Kg)	9.6	8.4	9.3
Per Herd Yield (Kg)	13.7	18.5	15
Average Price (Ksh. /Kg)	20.4	35.3	24.4
Average Revenue/herd	280.8	653.4	381.9
Total Cost (Ksh.)	35.4/= per kg (485.5/=herd)	38.0/= per /kg (703.3/= per herd)	37.4/=kg (551.1/= per herd)

<sup>a</sup> The standard deviation in parenthesis

The average prices for concentrate feeds and mineral supplements per kilogram and labour wage per hour were Kshs. 21.0, 138.5, 148.9, respectively. The costs of Napier per kilogram were Ksh. 1.4 in Embu East and 2.6 in Igembe South Districts.

### 3.1 Production Frontier and Technical Efficiency Estimates

Appendix 1 shows the summarized results of the maximum likelihood estimates of Cobb-Douglas stochastic frontier production function for dairy cow farms in Embu and Meru Counties. The results show that milking herd size, roughages, concentrates and mineral supplements were significant at 1% level; while labour was significant at 5% level. Results for separated regions (Embu East and Igembe South Districts) are presented.

#### 3.1.1 Technical Efficiency Levels

Dairy farm efficiencies ranged between 37.2 and 96.9%, with mean estimate of 83.7% (appendix 1). This mean efficiency level indicates that only a small fraction (16.3 percent) of the output can be attributed to wastage. Table 2 shows the frequency distribution of the dairy farm efficiencies. Over three quarters of the farms achieved efficiencies above 70% level.

Table 2: Frequency of technical efficiencies among dairy farmers in Embu and Meru Counties

	Embu E (n=96)	Igembe S (n=39)	Overall (n=135)
Percentage Class	Frequencies (%)		
0-39	1.0	0	0.7
40-49	0	10.3	3
50-59	4.2	5.1	4.4
60-69	2.1	7.7	3.7
70-79	12.5	15.4	13.3
80-89	37.5	35.9	37
90-100	42.7	25.6	37.8
Further Information on the Efficiencies			
Max	96.9	94.8	96.9
Min	37.2	41.3	37.2
Mean	85.5	79.3	83.7
Std dev	10.4	15.4	12.3

### 3.2 MLEs of Stochastic Frontier Cost Function

The stochastic frontier costfunction estimates of dairy cow farms in Embu East and Igembe South districts (pooled) are presented in Table 3. The cost elasticities with respect to output and input prices had a positive effect on costs. The output elasticity though positive was not significant. The results show that roughages and labour were significant at 1% level. There was no strong empirical support for diseconomies of scale as the coefficient of output<sup>2</sup> while positive, was not statistically significant. Cost elasticity with respect to roughages indicates diseconomies of scale, given the statistically significant positive coefficient of rfeed<sup>2</sup>.

Table 3: Parameters of the Translog Stochastic Cost Frontier Model for Milk Production in Embu and Meru in Kenya

Regressors	Parameter	Coefficient	Standard Error
Output	$\beta_1$	0.03	0.04
Roughages	$\beta_2$	0.27 (3.34***)	0.08
Minersuppls	$\beta_3$	0.05	0.07
Labour	$\beta_4$	0.46 (5.57***)	0.08
Output*Output	$\beta_5$	0.03	0.03
Roughage*Roughage	$\beta_6$	0.38 (3.57***)	0.11
Miner.suppls*Miner.suppls	$\beta_7$	0.11	0.98
Labour*Labour	$\beta_8$	0.06	0.05
Output*Roughages	$\beta_9$	0.03	0.05
Output*Miner.suppls	$\beta_{10}$	0.02	0.02
Output*Labour	$\beta_{11}$	-0.02	0.06
Roughage*Miner.suppls	$\beta_{12}$	-0.08	0.06
Roughage*Labour	$\beta_{13}$	-0.15 (-2.33**)	0.06
Miner.suppls*Labour	$\beta_{14}$	0.03	0.04
Sigma-squared		0.00**	0.01
Gamma		0.82***	0.11

\*\*\*, \*\*Significance level at 1%, and 5% respectively

Diagnostic statistics

Log likelihood function = 271.97

LR test of the one-sided error = 17.67

Note: All explanatory variables are in natural logarithms.

**Cross-Elasticities:** The coefficient for rfeedlabr was negative and significant at 1% level.

### 3.2.1 Cost Efficiency Estimates

The discrepancy between observed cost and the frontier cost is due both to technical and allocative inefficiencies. Results showed cost efficiency estimates ranging from a low of 1.01 to a high of 1.14, with an average efficiency estimate of 1.044. The means for Embu East and Igembe South Districts were 104.8 and 103.4 respectively.

### 3.3 Potential Reduction in Cost of Milk Production through Optimized Efficiencies

In a case of optimized technical efficiency from 83.7% to 100%, milk yields could rise from an average yield of 15 kg to 17.9, i.e.

$$100\% (\text{optimal technical efficiency}) / 83.7\% (\text{achieved TE}) * 15 (\text{Achieved yield}) = 17.9 \text{ kg}$$

This yield increase could result from efficiency optimization without addition of inputs. This would imply a decrease in cost of producing a kilogram of milk, as shown below;

The original cost per kilogram was;

$$(i). \text{Ksh. } 551.1 \text{ per herd} / 15 \text{ kg (average herd yield)} = \text{Ksh. } 37.4.$$

New cost in case of optimized technical efficiency;

$$\text{Ksh. } 551.1 \text{ per herd} / 17.9 (\text{anticipated herd yield}) = \text{Ksh. } 30.8$$

The difference in the cost of producing a kilogram of milk resulting from optimized TE could be;  $\text{Ksh. } 37.4 - 30.8 = \text{Ksh. } 6.6$ .

Potential cost reduction through optimized cost efficiency was obtained by undertaking the following computations; Cost reduction based on potentially optimized cost efficiency (CE);

$$100\% (\text{optimal efficiency}) / 104.4 (\text{achieved CE}) * \text{Ksh. } 37.4 = 35.8$$

This showed that cost reduction resulting from optimized cost efficiency could be;

$$\text{Ksh. } 37.4 - 35.8 = \text{Ksh. } 1.6$$

The potential average cost of producing a kilogram of milk in a case of optimized technical and cost efficiencies in the study area could therefore be;

$$\text{Ksh. } 37.4 - (6.6 + 1.6) = \text{Ksh. } 29.2$$

#### 4.0 Discussion and Conclusions

An increase in the number of milking cows could increase milk yields per farm in the study Counties. Similarly, Cabrera *et al.* (2009) showed that the variable with the highest impact on production was the number of cows on the farm. Further, Bhuyan and Postel (2009) found an additional milk cow in USA typically adding 11900 kg of milk to annual farm production. However, a dairy cow in the study area yielded only about one quarter of the USA cow per annum. An increase in herd size would require a proportionate increase in cheap key inputs such as feed and labour. An average farm in the study area having about two acres of land accommodated a homestead, dairy cattle (as many as four), other livestock species and various crop types. This contradicts the recommendation of having an acre of land established with Napier per cow and its follower (MoLD, 2003).

Farms underfed their dairy animals leading to reduced milk yields per cow, relative to their genetic potential. Dependence on rain-fed fodders and pastures on small land sizes was a plausible reason for inadequate roughages. Similarly in western Kenya, inadequate roughages constrain dairy productivity among smallholder farmers (Owuor and Ouma, 2009).

Roughage feeds contributed the highest proportion (53.9%) of the total cost of milk production in the study farms. Many other studies including Alvarez *et al.* (2005, 2008) and Lucila *et al.* (2005) had close results to those of this study. There were no economies of scale in relation to the costs of the roughages. According to Pichet, scientific evidence from many developed dairy producing countries show that milk production is much more dependent on the quantity and quality of feed rather than on the genetic makeup of the animal. The implication of this finding is that dairy farming will depend on adequate and affordable roughages, which could be better achieved where farm sizes are not severely limited. The policy makers can also come up with measures to improve on rain water catchment, storage and use.

Dairy farms provided an average of 2.2 kg concentrate feeds to supplement the roughages. It was not clear why farmers in the country use almost equivalent amounts. Lukuyu *et al.* (2011) and Njarui *et al.* (2011), found farmers providing concentrates based on the flat rate of 2 kg per cow per day. The quantity of concentrates fed to dairy cows correlated positively with milk yields in the study area. An increase of concentrates by 10% increased milk yield by 5.9%. Alemdar (2010), Saravanakumar and Jain (2007) and Binici (2006) reported close results to those of this study. The plausible reasons for underfeeding animals with concentrates were its cost, farmers not keeping production records, lack of information on its importance and learning from the other practicing farmers and less from the extension service providers.

This study found an increase in mineral supplements by 10% increasing the milk yield by 2.8%. Unfortunately, the average amount of mineral supplements provided per cow per month was only 1.1 kg as opposed to an average of 3 kg per month at 100 g/day (MoLD, 2003). Although some minerals are present in roughages and concentrates, dairy cows require regular supply of additional minerals. This could be achieved by providing on a daily basis access to commercial mineral supplements.

The number of labour hours invested in dairy farming was 37% above recommended 1.6 hours per cow per day (MoLD, 2003). Excessive labour input abnormally raises the cost of milk production, which is unfortunate considering that the farmers are usually price takers on both labour input and milk. The long distances between the dairy farm and the other owned plot(s) could be the probable cause of exaggerated labour input. FIAS (2006) found farmers in Pakistan employing approximately 50% labour input above the minimum recommendation. Labour productivity on smallholder dairy farms could be improved by adopting better farm management practices (efficiency improvement), expanding dairy herd sizes (increase in operational scale) and increasing milk yields (mainly per cow milk yields).

This study showed that roughages and labour substitute for one another in milk production, so costs are reduced by using them together. Kavoi *et al.* (2010) in a study on measurement of economic efficiency for smallholder dairy cattle in the marginal zones of Kenya reported similar findings. This implies that efficiency in labour utilization (which would reduce labour demand) is one of the options for decreasing dairy farming costs. Further, increased efficiency in roughage use would reduce wastage, thereby reducing the labour demand, which could decrease the total cost. In a case where quality roughages are available at a lower cost than would be grown by the farmer, then, that would lead to a decrease in labour costs and at the same time the total dairy farming costs.

#### 4.1 Technical Efficiency Levels

The dairy farms achieved an average efficiency of 83.7%, implying that in the short-run, there is a scope for increasing milk production by about 16.3% without increasing the current input level. This could be achieved by motivating the farmers through policy changes that are geared towards reducing dairy input costs and making milk prices predictable. Other studies on technical efficiency on dairy farming that reported almost equal mean efficiency levels include; Cabrera *et al.* (2009) and Alemdar (2009). Milk yields would more than double if all the inputs in use at the moment were to be proportionately doubled, as indicated by the total output elasticity of 2.11, implying that dairy farmers could benefit from economies of scale linked to increasing returns.

#### 4.2 Cost Efficiency Estimates

There was a discrepancy between each farm and its best practice cost, with farms operating at about 4.4% higher costs, resulting mainly from both technical and allocative inefficiencies. This finding however, indicates that the farmers in Embu and Meru Counties performed well at cost management. Smallholder dairy farms in six provinces of Northeast Thailand operate at 26% above the frontier costs (Lucila *et al.*, 2005). Kavoi *et al.* (2010) found smallholder dairy farmers in the transitional zones of Machakos and Makueni Districts of Kenya operating at 27.45% above the minimum costs. He found road infrastructure, extension and credit facility being significant in reducing cost inefficiency. Farmers could lower their milk production costs in the study area by maintaining an optimal milking cow-herd size and using yield-enhancing technologies. Feed technology options that could potentially reduce costs while maintaining yield levels are also necessary.

#### 4.3 Potential Reduction in Cost of Milk Production through Optimized Efficiencies

The continued liberalization of world trade and the accelerating international competition for markets, require farmers to consider the competitiveness of their products (Roche and Newman, 2008). The cost of producing a kilogram of milk in Embu and Meru Counties was US\$ 0.43 (US\$ 1=KES 85). According to the FAOSTAT and IFCN (2009), the following were the costs of producing a kilogram of milk in some other countries; Uganda (US\$ 0.26), Pakistan (US\$ 0.1), Vietnam (US\$ 0.15), Bosnia and Herzegovina (US\$ 0.3), and Argentina, Brazil, and New Zealand (varied between US\$ 0.07 to 0.17). This finding indicates that Kenya's milk remains uncompetitive in the market, making it inaccessible to both the citizens and their neighbours. Competitiveness in the market place for homogenous commodities such as milk is largely determined by costs of production.

#### 5.0 Conclusion

Dairy cows were underfed (received 52 kg of roughage against 100) and produced less milk than their genetic potential (9.3 kg against 20). The number of milking cows and quantities of roughages, concentrates and mineral supplements fed, were the major determinants of the amount of milk a farm produced. A proportionate doubling of all the inputs in use at the moment could more than double farm's milk yield.

The dairy farms achieved an average of 83.7% and 104.4% technical and cost efficiencies, respectively. The average cost of producing a kilogram of milk was Kshs. 37.4. The cost of roughages and labour constituted the highest proportion of the cost, and not the dairy farm inefficiencies. A skilful balancing act in the use of roughages and labour could lower the cost of milk production. Further, if both efficiencies were optimized, the cost of production could reduce by about 22%, from Kshs. 37.4 to 29.2, thus increasing its market access. The policy makers should discourage continued sub-division of agricultural land while concurrently promoting farm enterprise specialization and initiatives that lower the costs of dairy farming inputs. Such approaches require being engendered in the implementation of the Agricultural Sector Development Support Programme, which is currently at its initial stages.

## References

- Aigner, D.C., Lovell, K. and Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, (6), pp21–37.
- Alemdar, T., Behadir, B. and Oren, M.N. (2010). Cost and return analysis and technical efficiency of small scale milk production: A case study for Cukurova region, Turkey. *Journal of Animal and Veterinary Advances*, 9(4), pp 744-847.
- Alvarez, A., C. Arias, C., & Roibás, D. (2005). Análisis de la calidad de la leche en un modelo microeconómico multi-output: *el papel de la genética*. *Economía Agraria y Recursos Naturales*9(5), 3-17.
- Alvarez, A., J. del Corral, D. Solís and Pérez, J. A. (2008). Does intensification improve the economic efficiency of dairy farms? *J. Dairy Sci.*, 91, pp 3693–3698.
- Baltenweck, I., Yamano T., & Staal, S. J. (2006, August). *Dynamic changes in dairy technologies uptake in the Kenya highlands*. Poster paper prepared for presentation at the International Association of Agricultural Economists Conference. Gold Coast, Australia.
- Bebe, B.O. (2003). *Herd dynamics of smallholder dairy in the Kenya highlands*. (Unpublished Doctoral Dissertation). Wageningen Agric. University, Wageningen, The Netherlands.
- Bhuyan, S. and Postel M. (2009). *Determinants of organic dairy farm productivity: Some evidence from the north east United States*. In selected paper prepared for presentation at the agricultural & applied economics association's (AAEA) AAEA & ACCI Joint Annual Meetings. Milwaukee.
- Binici, T., Demircan, T. and Zulauf, C.R. (2006). Assessing production efficiency of dairy farms in Burdur province, Turkey. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, 107(1), pp 1–10.
- Burki, A.A., and Khan, M.A. (2007). *Milk Districts and Efficiency of Smallholder Dairy Producers in Pakistan*. Lahore University of Management Sciences, Pakistan.
- Cabrera, V. E., Solis, D. and Del Corral, J. (2009). Determinants of technical efficiency among dairy farms in Wisconsin. *J. Dairy Sci.* 93, pp 387–393.
- Charnes, A. C., Cooper, W. W. and Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, 2(6), pp 429–444.
- Chirwa, W. E. (2007, November). *Sources of technical efficiency among smallholder maize farmers in Southern Malawi*. Nairobi: African Economic Research Consortium.
- Coelli, T.J. (1996). *A Computer Program for Stochastic Frontier Production and Cost Function Estimation*. Centre for Efficiency and Productivity Analysis (CEPA). Australia. Retrieved from <http://www.une.edu.au/econometrics/cepawp.htm>.
- Edirisinghe, J.C, Edirisinghe, M.P. and Auwardt, D.M. (2007). Reasons for variations in the levels of efficiency in smallholder dairymilk production in Sri Lanka: A cross sectional data analysis. *Sri Lanka Journals On-Line*, 1(2). Retrieved from <http://www.sljol.info/index.php/JFA/search/titles>.
- Farrell, M.J. (1957). "The measurement of productive efficiency". *Journal of the Royal Statistical Society*, 120(3), 253-290.
- Foreign Investment Advisory Services (FIAS). (2006). Constraints to Competitiveness in the Dairy Sector: Pakistan Value Chain Analysis. Faisalabad, Pakistan.
- Gamba, P. (2006). Beef and Dairy cattle improvement services: A Policy Perspective. Tegemeo Working paper 23/2006, *Tegemeo Institute of Agricultural Policy and Development, Egerton University, Nairobi, Kenya*.
- IFCN. (2009, March 12). International dairy comparison network. Retrieved from [www.ifcndairy.org](http://www.ifcndairy.org).



- Jaetzold, R., Schmidt, H., Hornetz, B., and Shisanya, C. (2007). *Farm Management Handbook of Kenya Vol. II; Natural Conditions and Farm Management Information*. Nairobi: Ministry of Agriculture.
- Kahi, A.K., Nitter, G. and Gall, C.F. (2004). Developing breeding schemes for pasture based dairy production systems in Kenya. II. Evaluation of alternative objectives and schemes using a two-tier open nucleus and young bull system. *Journal of Livestock Production Science*, **88**, pp 179-192.
- Karanja, A.M. (2003). The dairy industry in Kenya: the post-liberalization agenda. In Paper presented at a dairy industry stakeholders workshop. Nairobi, Kenya. August, 2002. (1-60).
- Kavoi, M. M., Hoag, L., & Pritchett, J. (2010). Measurement of economic efficiency for smallholder dairy cattle in the marginal zones of Kenya. *Journal of Development and Agricultural Economics*, **2**(4), 122-137.
- Kimenju, S. C. and Tschirley, D. (2008). *Agriculture and livelihood diversification in Kenyan rural households*. Nairobi: Tegemeo Institute of Agricultural Policy and Development.
- Kokkinou, A. and Geo. (2009). *Stochastic frontier analysis: Empirical evidence on Greek productivity*. Glasgow. University of Glasgow.
- Kumbhakar, S.C. and Lovell, C.A.K. (2000). *Stochastic frontier analysis*. New York: Cambridge University Press.
- Lucila Ma. A., Lapar1a, Garcia, A., Adittob, S. and Suriyab, P. (2005, July). *Measuring cost efficiency in smallholder dairy: Empirical evidence from Northeast Thailand*. Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Providence, Rhode Island.
- Lukuyu, B., Franzel, S., Ongadi P. M. and Duncan, A.J. (2011). Livestock feed resources: Current production and management practices in central and northern rift valley provinces of Kenya. Retrieved from <http://www.lrrd.org/lrrd23/5/luku23112.htm>
- Makokha S.N., Karugia J., Staal S. and Oluoch-Kosura. (2007). Analysis of factors influencing adoption of dairy technologies in Western Kenya. A paper presented in AAAE Conference Proceedings in Accra, Ghana.
- Meeusen, W. and van den Broeck, J. (1977). Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error. *International Economic Review*, **18** (2), pp 435-444.
- MoLD. (2003). *Livestock production management and practices manual*. Nairobi, Kenya.
- MoLD. (2010). Kenya national dairy master plan. (1) A Situational analysis of the dairy sub-sector. Nairobi, Kenya.
- Moreira, V. H. and Bravo-Ureta, B.E. (2010). "Technical efficiency and metatechnology ratios for dairy farms in three Southern Cone Countries: A stochastic meta-frontier model." *Journal of Productivity Analysis*, **33**(1), pp 33-45.
- Ngigi, M. (2002). *An evaluation of the impacts of transaction costs and market outlet risks on market participation of smallholder dairy farmers in central*. (Unpublished Doctoral Dissertation). University of Nairobi, Nairobi, Kenya.
- Njarui, D. M. G, Gatheru M., Wambua, J. M, Nguluu, S. N., Mwangi, D. M. and Keya, G. A. (2011). Feeding management for dairy cattle in smallholder farming systems of semi-arid tropical Kenya. Retrieved from <http://www.lrrd.org/lrrd22/3/onga22056.htm>
- Omiti, J., Wanyoike, F., Staal, S., Delgado, C. and Njoroge, L. (2006, August). *Will small-scale dairy producers in Kenya disappear due to economies of scale in production?* Contributed paper prepared for presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia.
- Ongadi, P.M, Wahome, R.G, Wakhungu, J.W. and Okitoi, L.O. (2006). Modeling the influence of existing feeding strategies of performance of grade dairy cattle in vihiga, Kenya. Retrieved from <http://www.lrrd.org/lrrd22/3/onga22056.htm>

Owuor, G. and Ouma, A.S. (2009). What are the key constraints in technical efficiency of smallholder farmers in Africa? *Empirical evidence from Kenya*; 111 EAAE-IAAE Seminar 'Small farms: decline or persistence' University of Kent, Canterbury, UK 26th. - 27th. June 2009.

Pichet, S. "The Development of Dairy Farming in Thailand." Unpublished manuscript. (undated)

Reifschneider, D. and Stevenson, R. (1991). Systematic Departures from the frontier: A Framework for the Analysis of Firm Inefficiency. *International Economic Review*, **32**(3), pp 715-723.

Republic of Kenya (RoK), (2009). Ministry of State for Planning, National Development and Vision 2010. Kenya National Census. Nairobi: Government Press.

Roche, J.R. and Newman, M. (2008, June). Profitable low input systems. Separating the myth from the magic. Proceedings of the South Island Dairy Event. June 23- 25 2008, Invercargill, New Zealand. pp. 81-91. Retrieved from [http://www.dairynz.co.nz/page/pageid/2145859470/Dairy\\_Industry\\_Conference\\_Publications](http://www.dairynz.co.nz/page/pageid/2145859470/Dairy_Industry_Conference_Publications)

Saravanakumar, V., and Jain, D. K. (2007). Technical efficiency of dairy farms in Tamil Nadu. In Poster Presented in the International Conference on Statistics and Informatics in Agricultural Research, from 27th to 30th December, 2006 at IASRI, New Delhi, India.

Staal S. J., Alejandro, N. P. and Jabber, M. (2008). Dairy development for the resource poor Part 2: Kenya and Ethiopia dairy development case studies pro-poor livestock policy initiative. Retrieved from [http://www.igad-lpi.org/publication/docs/IGADLPI\\_WP\\_MK.pdf](http://www.igad-lpi.org/publication/docs/IGADLPI_WP_MK.pdf)

William G., and Juan, M. (1985). Operating Cost Efficiency on Pennsylvania Dairy Farms. Massachusetts: Heffernan Press.

**Appendix 1: Maximum likelihood estimates of Cobb-Douglas stochastic frontier model for Dairy Cow Farmers**

Variable	Both Study Areas			Embu East			Igembe South		
	Coefficient	Standard Error	t-ratio	Coefficient	Standard Error	t-ratio	Coefficient	Standard Error	t-ratio
Constant	-20.31	0.29	-0.01	-0.22	0.33	-0.68	-1.44	0.86	-0.18
Herd Size	0.06	0.10	0.51	0.09	0.13	0.69	-0.20	0.72	-0.28
Milking Herd Size	0.76	0.11	6.85** *	0.07	0.12	5.70* **	1.09	0.32	3.43* **
Breed	0.05	0.08	0.58	0.07	0.10	0.74	-0.29	0.22	-1.33
Roughage Feeds	0.51	0.17	3.02** *	0.64	0.20	3.18* **	1.18	0.52	2.25* *
Concentrate Feeds	0.59	0.09	6.4***	0.59	0.10	6.18* **	0.44	0.24	1.79* **
Mineral Supplements	0.28	0.07	4.00** *	0.21	0.07	2.78* **	0.81	0.39	2.11* *
Labour	-0.19	0.09	-2.14**	-0.20	0.11	-1.77	-0.03	0.28	-0.09
Land Size	0.07	0.09	0.84	0.09	0.10	0.87	-0.08	0.45	-0.17
Chaff-cutter	-0.03	0.04	-0.78	-0.01	0.05	-0.22	-0.04	0.37	-0.10
<b>Variance Parameters</b>									
$\sigma^2$	1.32	1.94	0.68	1.03	1.04	0.99	0.05	0.11	0.50
$\Gamma$	0.98	0.02	54.38	0.98	0.02	5.50	0.28	0.95	0.30
	Mean	TE	83.7		86.7			92.0	
	(%)								

\*, \*\* and \*\*\* significant at 10, 5 and 1 percent significance levels, respectively.

Source: Computations from Frontier 4.1c