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# Evaluation of Technical Efficiency of Dairy Farms in Eastern Central Highlands, Kenya

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***Abstract:***
*Despite Kenya's long dairy farming history spanning about 100 years, favourable climatic conditions and a 3.5 million national herd, milk per capita consumption is low (76.7 kg) and export quantities (milk) to the regional market where its products enjoy preferential access are negligible. These observations raised the question of farm level technical efficiency of milk production. This study evaluated the technical efficiency of dairy cow farms in Embu and Meru counties of Kenya, using the stochastic frontier approach. Data were randomly collected from 135 dairy farms. The sample size was determined using the Cochran's (1977) formula. Data were analyzed using the SPSS, Frontier 4.1 c and STATA computer softwares, where both descriptive and inferential statistics were derived. Stochastic frontier production function was estimated using the maximum likelihood estimation technique. The farms were characterized and technical efficiency estimated. Results revealed that the number of lactating cows and the amounts of roughages, concentrates, and mineral supplements were the major factors influencing milk output. The dairy animals received inadequate feeds and mineral supplements. The animals were overstocked and underfed in an average two-acre mixed crop-livestock farm. The mean farm technical efficiency was 83.7%, implying that milk production could be increased by 16.3% through better use of available resources, given the current state of technology without extra cost. The milk production model coefficient was 2.11. It was recommended that farmers specialize in either dairy or crop farming. Those choosing dairying, require shifting from the Friesians and Ayrshires to the smaller dairy breeds such as Jerseys. The policy makers should provide legal guidelines to ensure that sub-division of agricultural land is minimized and further, promote both enterprise specialization and approaches that make the farm inputs such as concentrates and mineral supplements affordable.*

***Key words:*** *Technical and cost efficiency, stochastic frontier, smallholder dairy farming*

## 1. Introduction

Kenya's dairy sub-sector spans about a century and ranks among the largest in sub-Saharan Africa (Ngigi, 2004). The national herd size is approximately 3.5 million (RoK, 2009). The sub-sector 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).

Despite the apparent positive status of dairy farming in Kenya, various indicators show that the sector is under performing. South Africa, a country whose dairy herd size averages 0.5 million, produced about 3 billion kg of milk in 2009, while Kenya's herd of 3.5 million managed about 4 billion kg (Wambugu and Kirimi, 2010). With the same yield proportionality, Kenya would have produced over 20 billion kilograms. Unfortunately Kenya's per cow yield has remained at an average of 6 kg over the last 30 years (MoLD, 2010). The country's per capita milk consumption is about 76.7 kg, while the WHO's recommendation is 200 kg (FAO, 2007). The surplus milk in Kenya would access the regional market where the country's products enjoy preferential treatment. This is mainly through benefits bestowed to the members of the regional trade blocks such as East African Community (EAC) and Common Market for East and Southern Africa (COMESA) (RoK, 2007). The amount of Kenyan milk sold to this market is however, negligible.

Various studies on diverse aspects of 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. Some of the areas covered by past studies include: production systems (Bebe, 2003); genetics (Kahi et al, 2004); nutrition (Ongadi et al, 2006); farm-level milk production (Gamba, 2006; Baltenweck, 2006; Kimenju and Tscherley, 2008); smallholder dairy profitability (Omiti et al, 2006) and farmers' adoption of production technologies (Makokha et al, 2007). Although many recommendations were made from such studies, the required gains have not yet been made. A need for better understanding of the technical efficiency of dairy farms in the country arose and became the focus of this study.

The present paper estimates the technical efficiency 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). Technical efficiency estimation provides an indication of the percentage by which potential output could be increased 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. 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 $0030^0$ S, $37\ 30^0$ E and Meru at $0^0$, $38\ 00^0$ E. They cover an area of 2826.4 and 6924 $km^2$, 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-$28^0$C (Jaetzold et al, 2007). 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.

### *2.2. Stochastic Frontier Production 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;

$Y_i = f(x_i; \beta) + \varepsilon_i$ where, i=1, 2,…, N (1)

$\varepsilon_i = v_i - u_i$ (2)

where, $Y_i$ represents the output level of the $i^{th}$ 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 $i^{th}$ 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*

- 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;

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

Where;

ln represents logarithm to base e; subscripts ij refers to the jth observation of the ith 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.

## 3. Results

The results on farm characterization and other related variables are as summarized below table 1). 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*

Table 2 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.

| **Item** | **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[a]) | 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) cow/day |
| Mineral supplements (kg) | 4.2 (3.3) | 4.5 (4.0) | Average; 1.1 (3.5) 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) |

*Table 1: A Summary of Descriptive Statistics of Select Study Variables*
*[a] The standard deviation in parenthesis*

| | Both Study Areas | | | Embu East | | | Igembe South | | |
|---|---|---|---|---|---|---|---|---|---|
| | Coefficient | Standard-Error | t-ratio | Coefficient | Standard-Error | t-ratio | Coefficient | Standard-Error | t-ratio |
| **Variable** | | | | | | | | | |
| Constant | -20.31 | 0.29 | -0.01 | -0.22 | 0.33 | -0.68 | -1.44 | 0.86 | -0.1.8 |
| 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 |
| **Variance Parameters** | | | | | | | | | |
| $\sigma^2$ | 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 | |

*Table 2: Maximum likelihood estimates of Cobb-Douglas stochastic frontier model for Dairy Cow Farmers*
**, ** and *** significant at 10, 5 and 1 percent significance levels, respectively.*
*Source: Computations from Frontier 4.1c*

### *3.2. Technical Efficiency Levels*

Dairy farm efficiencies ranged between 37.2 and 96.9%, with mean estimate of 83.7% (table 2). This mean efficiency level indicates that only a small fraction (16.3 percent) of the output can be attributed to wastage. Table 3 shows the frequency distribution of the dairy farm efficiencies. Over three quarters of the farms achieved efficiencies above 70% level.

| | 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 |

*Table 3: Frequency of technical efficiencies among dairy farmers in Embu and Meru Counties*

## 4. Discussion and Conclusion

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 11 900 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 contradicted 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). According to Pichet (undated), 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.

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).

### *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 (2010). 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.

## 5. Conclusion

Dairy cows are underfed (received 52 kg of roughage against 100) and produce 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, determine the amount of milk a farm produces. The dairy farms operate at an average of 83.7% technical efficiency, implying that one can lower the milk production inputs by 16.3% without reducing the milk output quantities. A proportionate doubling of all the inputs in use at the moment could more than double a farm’s milk yield. It is recommended that the policy makers initiate measures to discourage continued sub-division of agricultural land while concurrently promoting farm enterprise specialization.

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