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Evaluation of Technical Efficiency of Dairy Farms in Embu County, Kenya

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Abstract:
Dairy farming in Kenya is a major economic activity accounting for 3.5% of the national GDP and contributes to household incomes, food and employment. However, despite Kenya's long dairy farming history spanning about 100 years, favourable climatic conditions and a 3.5 million national herd, its milk per capita consumption is low (76.7 kg) and export quantities (milk) remain negligible. These observations raised the question of the performance of the farms, particularly their level of technical efficiency. This study evaluated the technical efficiency of dairy cow farms in Embu county of Kenya, using the stochastic frontier approach. Data were randomly collected from 96 farms. The sample size was determined using the Cochran's (1977) formula. Data were analyzed using the SPSS and Frontier 4.1 c computer softwares. Stochastic frontier production function was estimated using the maximum likelihood estimation technique. The farms were characterized and their technical efficiencies estimated. Results revealed that the number of lactating cows and the amounts of roughages, concentrates, and mineral supplements were the major variables influencing milk output. The dairy animals received inadequate nutrients. The animals kept exceeded the farm's carrying capacity. The mean farm technical efficiency was 85.5%, implying that milk production could be increased by 14.5% through better use of available resources, given the current state of technology without extra cost. The milk production model coefficient was 1.33. It was recommended that farmers specialize in one agricultural enterprise (dairy or crop farming) resulting from the small land sizes owned. Those choosing dairying, require shifting from the Friesians and Ayrshires to the smaller dairy breeds such as Jerseys. The policy makers require coming up with regulations that encourage enterprise specialization and discourage continued sub-division of agricultural land.

Keywords: *Technical efficiency, stochastic frontier, smallholder dairy farming*

1. Introduction

Dairy production is a major farm activity in Kenya, incorporating over 1.8 million smallholder farm households, who produce over 70% of all milk marketed (SDP, 2005). The national herd size is approximately 3.5 million (RoK, 2009). It accounts for about 3.5% of the National gross domestic product (GDP) and contributes to the livelihoods of many small-scale farmers through income, employment and food (Omiti *et al*, 2006). Smallholder dairy production in Kenya has thrived since independence in 1963 owing to supportive subsidized services, and guaranteed milk markets and prices for farmers (Ngigi, 2004).

Despite the apparent positive status of dairy farming in the country, various indicators show that the sector is not optimally 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). Kenya's per cow yield has consistently remained at an average of 6 kg for more than 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 remains negligible.

Different 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. 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 County 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 County is found on the Eastern Central highlands of Kenya, lying at 0030^0 S and 37 30^0 E. It covers an area of 2826.4 km^2. Embu County has two rain seasons; March to May and October to December. The annual rainfall totals range in-between 600-2200. The temperature ranges between 12-27^0C (Jaetzold *et al*, 2007). The county borders Mt. Kenya and is ideal for dairy farming. It has a human population of 516,212 (RoK, 2009).

The sample for this study was drawn from Embu East district within Embu County. 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.

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;

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

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

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, β, of unknown parameters. ε_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;

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

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 were as summarized in table 1.

Item	Finding
Average herd Size	3.89
Milking herd size	1.61cows-lactating
Breed	53% Friesian, 22% Ayrshire, 5% Guernsey, 5% Jersey and 15% crosses
Roughage feeds fed (kg)/cow/day	51.9 (11.6[a])
Concentrate feeds (kg)/cow/day	2.2 (1.2)
Mineral supplements (kg)/herd/month	4.2 (3.3)
Labour time (Hrs)/ cow/day	2.1
Land size average/farm	2.0
Chaff-cutter ownership	25%
Per Cow Yield (Kg)/day	9.6
Per Herd Yield (Kg)/day	13.7
Average Price (Ksh. /Kg)	20.4

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

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 County. The results show that milking herd size, roughages, concentrates and mineral supplements were significant at 1% level.

Variable	Coefficient	Standard-Error	t-ratio
Constant	-0.22	0.33	-0.68
Herd Size	0.09	0.13	0.69
Milking Herd Size	0.07	0.12	5.70***
Breed	0.07	0.10	0.74
Roughage Feeds	0.64	0.20	3.18***
Concentrate Feeds	0.59	0.10	6.18***
Mineral Supplements	0.21	0.07	2.78***
Labour	-0.20	0.11	-1.77
Land Size	0.09	0.10	0.87
Chaff-cutter	-0.01	0.05	-0.22
Variance Parameters			
σ^2	1.03	1.04	0.99
γ	0.98	0.02	5.50
		86.7	

Table 2: MLEs of Cobb-Douglas stochastic frontier model for Embu County Dairy Farms
**** Significant at 1 percent significance levels*
Source: Computations from Frontier 4.1c

3.2. Technical Efficiency Levels
Dairy farm efficiencies range between 37.2 and 96.9%, with mean estimate of 85.5% (table 3). This mean efficiency level indicates that only 14.5 percent of the output can be attributed to wastage. Table 3 shows the frequency distribution of the dairy farm efficiencies. Over four fifth of the dairy farms operated at efficiencies above 80%.

Percentage Class	Frequencies (%)
0-39	1.0
40-49	0
50-59	4.2
60-69	2.1
70-79	12.5
80-89	37.5
90-100	42.7
Further Information on the Efficiencies	
Max	96.9
Min	37.2
Mean	85.5
Std dev	10.4

Table 3: Frequency of technical efficiencies among dairy farms in Embu County

4. Discussion and Conclusions

An increase in the number of milking cows increases milk yield in Embu County. Cabrera *et al.* (2009), similarly, found the number of cows on the farm having the highest impact on milk production. 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. An increase in herd size would require a proportionate increase in 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 an acre of land established with Napier per cow and its follower (MoLD, 2003) in Kenya's highlands.

Farms underfed their cows leading to reduced milk production relative to their genetic potential. Dependence on rain-fed fodders and pastures on small land sizes was a plausible reason for inadequate roughages. This appears to be a common practice in Kenya's dairy keeping regions. Inadequate roughages constrain dairy productivity among smallholder farmers in Western Kenya (Owuor and Ouma, 2009). According to Pichet (undated), scientific evidence from many developed 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 future milk production in Kenya remains bleak unless the continued land sub-division trend is reversed.

Embu County farmers provided an average of 2.2 kg concentrates per cow per day to supplement the roughages. It was not clear why farmers in Kenya 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. The quantity of concentrate 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, inadequate production records, lack of information on its significance and depending on information from the other farmers and less from the extension service providers.

This study revealed that an increase in mineral supplements by 10% could increase 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 (MoLD, 2003). Although some minerals are present in roughages and concentrates, dairy cows require regular supply of additional commercial mineral supplements on a daily basis.

Embu County dairy farmers allocated 39% more labour hours above the recommended 1.6 hours per cow per day (MoLD, 2003). The plausible reason for this was that the roughages were sourced from outside the farm. Such a scenario raises the cost of milk production, making it unaffordable. It is also notable that the situation is regrettable considering that the farmers in the County are price takers on both labour input and milk. 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 per cow.

4.1. Technical Efficiency Levels

The dairy farms in the study County operate at an average technical efficiency of 85.5%. This finding implies that in the short-run, there is a scope for increasing milk production by about 14.5% without increasing inputs or reducing them by the same margin without lowering the yield. 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). The model coefficient was 1.33, implying that dairy farmers could benefit from economies of scale linked to increasing returns.

5. Conclusion

Embu County dairy farmers own high quality breeds that produce relatively low milk quantities due to the inadequate nutrients provided. A further improvement of the breed cannot raise milk yields. The number of milking cows and the provided quantities of roughage, concentrates and mineral supplements determine the amount of milk a farm produced. Cows received an average of 52 kg of roughage against a recommendation of about 100 and produced 9.3 kg of milk against a potential of 20. The small size of land owned (average 2 acres) cannot allow for an increase in the number of milking cows. The dairy farms operated at an average of 85.5% technical efficiency, implying that one can lower the milk production inputs by 14.5% without reducing the milk output quantities. Dairy farms in the study county have an opportunity to enjoy the economies of scale, linked to increasing returns. It is recommended that the policy makers come up with regulations that encourage enterprise specialization and discourage continued sub-division of agricultural land.

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