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Estimation of Cost Efficiency of Dairy Farms in Kenya's Eastern Central Highlands

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Abstract:

The objective of this study was to determine the cost efficiency of dairy cow farms in the Eastern Central highlands of Kenya. The data was collected through a cross-sectional survey from 135 farms in the study region. The sample size was determined using the Fischer's formula. A stochastic frontier cost function was estimated using the maximum likelihood estimation technique. The MLE results revealed that the costs of roughages and labour were the major determinants of dairy farming cost. The farms operated at low economies of scale, mainly because the land size owned averaged only two acres; where mixed crop-livestock farming was practiced. It was revealed that roughages could substitute with either mineral supplements or labour to reduce farming costs. The mean farms cost efficiency index was 4.4% above the frontier cost. Most farms did not make profits. The average cost per farm was Ksh. 551 while the milk revenue was Ksh.365. It was concluded that farmer-cost inefficiency was not the main cause of the high milk production cost. The cost of feeds coupled with the relatively small land sizes owned and the cost of labour were the main challenges facing dairy farming in the study region. It was recommended that policy makers come up with necessary laws and regulations to ensure that the continued land sub-division is reversed and that the cost of dairy farming inputs is reduced. Researchers require establishing the least-cost combination ratio for roughage and labour.

Keywords: Cost efficiency, milk production cost, stochastic frontier

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 (MoSPND, 2009). The sub-sector accounts for about 3.5% of the National gross domestic product (GDP) and contributes to the livelihoods of about four million Kenyans through food, income and employment (Omiti *et al*, 2006). Several factors, which include the presence of significant dairy cattle populations, the historical importance of milk in the diets of most Kenyan communities and a suitable climate for dairy cattle have contributed to the successful dairy keeping in Kenya (Conelly, 1998; Thorpe *et al*, 2000).

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). Kenya's per cow yield, unfortunately, has remained at an average of 6 kg over the last 30 years (MoLD, 2010). Its average local price is much above that at the global market. It is not affordable by many in the country. 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 (if affordable) 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 (SDP, 2006; 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 are yet to be made. What is notable from the described scenario is that Kenya has failed to produce enough and affordable milk for both local and export market. There is therefore need for better understanding of the production and cost efficiency of dairy farms in the country.

The present paper estimates the cost efficiency of dairy farms in Kenya's Eastern Central highlands. 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). Cost efficiency estimation provides an indication of the percentage by which potential cost could be reduced in relation to the corresponding cost frontier.

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), the thick frontier approach (TFA), Data Envelopment Analysis (DEA) (Charnes *et al.*, 1978) and the free disposal hull (FDH). The present paper estimates the cost efficiency following the stochastic cost frontier approach.

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° S, 37 30° E and Meru at 0°, 38 00° E. They cover an area of 2826.4 and 6924 km², 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 (MoSPND, 2009).

The sample for this study (proportionate) was drawn from Embu East (96) and Igembe South (39) 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 Cost Frontier function

To measure the cost efficiency of individual dairy farms, the stochastic frontier methodology of Aigner *et al.* (1977) was used. In this method, a dairy farmer's observed total cost is modeled to deviate from the cost-efficient frontier due to random noise and possibly cost inefficiency. For the i^{th} firm,
$$\text{LnTC}_i = f(\text{ln}Y_i, \text{ln}w_j) + \varepsilon_i \quad (1)$$

where TC_i is the total cost, Y_i is milk output, and w_j are input prices. In equation 1, ε_i is a two-component disturbance term of the form:

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

where v_i represents a random uncontrollable factor and u_i is the controllable component of ε_i . In equation (2), v_i is independently and identically distributed with zero mean and σ_v standard deviation, i.e., $v_i \sim N(0, \sigma_v^2)$. The term u_i is distributed independently of v_i and has a half-normal distribution, i.e., u_i is the absolute value of a variable that is normally distributed with zero mean and standard deviation σ_u , $N+(0, \sigma_u^2)$.

2.3. Empirical Models

2.3.1. Empirical Model for Cost Efficiency estimation

In order to analyze the cost efficiencies of smallholder dairy farms in the study area, a stochastic cost frontier approach was adopted. A translog cost function was considered to concurrently explain the milk production and cost functions of the dairy farms; being the most flexible form of a cost function. The advantage of the translog specification over that of Cobb-Douglas is that the one-sided error component u_i now captures both input oriented technical and allocative inefficiency (Nadolnyak *et al.*, 2000, as quoted by Lucila *et al.*, 2005). The model was run using the FRONTIER 4.1c econometric software. Maximum likelihood estimation was employed to

estimate simultaneously the parameters of the stochastic translog cost frontier and the cost inefficiency model. The translog function (Christensen *et al.*, 1971) is specified as:

$$\ln (TC/cfeed) = \beta_0 + \beta_y \ln output + \sum_{jaj} \ln (p_j/cfeed) + 1/2 \beta_{yy} (\ln output)^2 + 1/2 \sum_j \sum_{hajh} \ln (p_j /cfeed) * \ln (p_h/cfeed) + \sum_{jayj} \ln output * \ln (p_j/cfeed) + v_i + u_i. (3)$$

where TC is the actual total cost of production; cfeed is average price of concentrate feed per day; the other input cost, p_j , are the input prices. 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 becomes:

$$tcost = \beta_0 + \beta_1 outpt + \beta_2 rfeed + \beta_3 minsuppls + \beta_4 labr + 1/2 \beta_5 outpt^2 + 1/2 \beta_6 rfeed^2 + 1/2 \beta_7 minsuppls^2 + 1/2 \beta_8 labr^2 + \beta_9 outptrfeed + \beta_{10} outptminsuppls + \beta_{11} outptlabr + \beta_{12} rfeedmin + \beta_{13} rfeedlabr + \beta_{14} minsupplslabr + v_i + u_i (4)$$

(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); outpt² = output x output; rfeed² = roughage feed x roughage feed (kg); minsuppls² = mineral supplements x mineral supplements (kg); labr² = 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; minsupplslabr= roughage feed x labour).

3. Results

The results on farm characterization were as summarized in table 1.

Item	Status	Recommended
Farm characteristics		
Total dairy cattle herd size	71.1% -2-5 animals (mean= 3.93)	Resource-based. 1 acre/cow-highlands
Milking Herd size	1.56 cows-lactating; 55.6% -1 cow	70-75% of the herd
Roughage feeds fed	Average; 52.2 (11.7 ^a) kg	Av.- 100 kg
Concentrate feeds	Av.- 2.18 kg/cow/day	Milk yield-based. Can go up to 10 kg/cow/day
Mineral supplements	Av.- 1.1 kg	Individual cow- based. Aprox. 3 kg/cow/month
Grazing mode	>96 % zero-grazing	Resource-based. Best for smallholder dairy cow farmers
Chaff-cutter technology	23.7%	100% to smallholder
Breed kept	75 % had Friesian &/Ayrshire	Resources-based
Land size	Average 2 acres. A cow gets less than half an acre.	1 acre established with Napier grass /cow & its follower in the highlands
Labour	Av.- 2.22 hrs/cow/day	1.6 hrs/cow/day
Milk production (kg)	9.3 kg/cow and 15 kg/farm	Av.-20 kg/cow
Milk price/kg	Av.-24.27= but 20.4= Embu & 35.18= in Meru	20= / kg-It's the global average
Extension service availability	32.6%	100%
Main source of household income	43.7% dairy cow, 25.9% salary/wage 25.9% crop farming 4.4% Retail businesses	None
Main challenges faced	32.6% cost of breeding stock, 31.1% cost of feeds, 10.4% bad weather	Not applicable

Table 1: A Summary of Descriptive Statistics of Select Study Variables

^a The standard deviation in parenthesis

3.1. The Stochastic cost Frontier Estimates

The stochastic frontier cost function estimates of the sampled dairy cow farms in both Embu East and Igembe South districts (pooled) are presented in Table 2.

Regressors	Parameter	Coefficient	Standard Error
Output	β_1	0.03	0.04
Roughages	β_2	0.27 (3.34***)	0.08
Minersuppls	β_3	0.05	0.07
Labour	β_4	0.46 (5.57***)	0.08
Output*Output	β_5	0.03	0.03
Roughage*Roughage	β_6	0.38 (3.57***)	0.11
Miner.suppls*Miner.suppls	β_7	0.11	0.98
Labour*Labour	β_8	0.06	0.05
Output*Roughages	β_9	0.03	0.05
Output*Miner.suppls	β_{10}	0.02	0.02
Output*Labour	β_{11}	-0.02	0.06
Roughage*Miner.suppls	β_{12}	-0.08	0.06
Roughage*Labour	β_{13}	-0.15 (-2.33**)	0.06
Miner.suppls*Labour	β_{14}	0.03	0.04
Sigma-squared		0.00**	0.01
Gamma		0.82***	0.11

Table 2: Parameters of the Translog Stochastic Cost Frontier Model for Milk Production in Embu and Meru in Kenya
 ***, ** 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.

Source: Computer print-out of Frontier 4.1c.

3.2. Cost Efficiency Levels

3.2.1. Cost Efficiency Estimates

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. The cost efficiency scores by each sampled dairy farm are presented in figure 1.

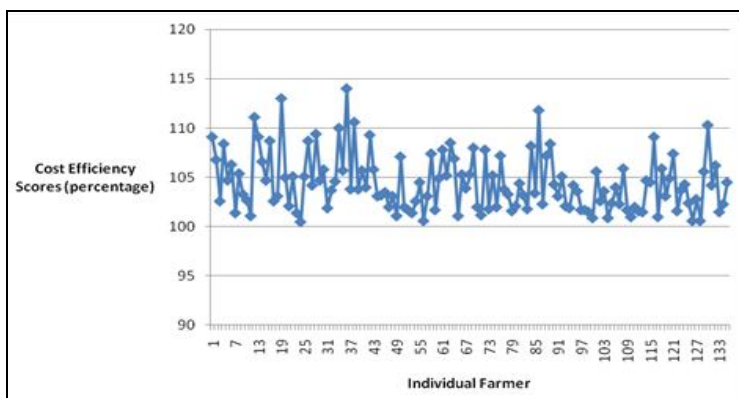


Figure 1: Distribution of Efficiency Scores by Dairy Farmers in Embu East and Igembe South Districts
 Source: Field survey results, 2012

4. Discussion and Conclusion

As expected, the cost elasticities with respect to output and input prices had a positive effect on costs, conforming to the basic properties of the cost function that satisfy the cost minimization assumption. It is not possible to produce a positive output with no costs, following the assumption on strictly positive prices and that at least one input is required to produce an output.

The obtained coefficients of roughage feeds (0.27) and labour (0.46) imply that an increase in each of the two variables could increase total costs. The two were statistically significant at 1% level. There was no strong empirical support for diseconomies of scale in milk production cost as the coefficient of $output^2$, though at positive 0.03, was not statistically significant. Cost elasticity with respect to roughage feeds (0.38) indicated diseconomies of scale, given the statistically significant positive coefficient of $rfeed^2$.

The coefficients for *rfeedminsuppls* (-0.08) and *rfeedlabr* (-0.15) were negative and significant at 10% and 1% levels respectively. The negative parameter estimates for *rfeed X minsuppls* and *rfeed X labr* indicates that roughage feed and mineral supplements; and roughage feed and labour, substitute for one another in production, so costs are reduced by mixing them.

Cost efficiency estimates ranged from a low of 1.01 to a high of 1.14, with an average efficiency estimated at 1.044. The discrepancy between the observed cost and the frontier cost is due both to technical and allocative inefficiencies. This discrepancy indicated that smallholder dairy farms in Eastern Central highlands of Kenya were operating at 4.4 percent higher costs than the best practice. It also implied that, on average, 4.4% of the costs incurred could be avoided without any decrease in total output, on condition that they operate on their efficient frontiers. Lucila *et al.* (2005) found smallholder dairy farms in six provinces of Northeast Thailand operating at 26% above the frontier costs. They recommended proper herd management with the view to maintaining an optimal milking cow-herd size ratio, coupled with yield-enhancing technologies to enhance cost efficiency. Feed technology options that could potentially reduce costs while maintaining yield levels were also recommended. William and Juan (1985) through an evaluation of farms by herd size groups, showed the average measure of cost efficiency to range from 170 to 180 percent. Kavoi *et al.* (2010) found smallholder dairy farmers in the transitional zones of Machakos and Makueni Districts of Kenya to range from 0.01 - 81.11 above the frontier cost, with a mean of 27.45%. Road infrastructure, extension and credit facilities were found to significantly reduce cost inefficiency.

On average, this study's finding was that the farmers in the study region had relatively high efficiency levels in terms of cost management. The costs of roughage feeds and labour were the two main areas that could be addressed to decrease the total costs. It must be mentioned that the status of the national economy and the economic policies under implementation contribute to the total cost of dairy farming through input prices. The main culprits here are the level of taxes on feed-making ingredients, cost of electricity, the level of road network connectivity and the bank interest rates. A dairy farmer to a large extent is unfortunately a price-taker when procuring inputs as well as when selling his milk. He does not have the opportunity to set prices of his products. The implication of this finding is that farmers in the study area can do very little to reduce the cost of milk production, through improvement in cost efficiency.

5. Conclusion

We analyzed the cost efficiency of smallholder dairy producers in the Eastern Central highlands of Kenya (Embu and Meru counties) using the stochastic cost frontier technique. Our results confirm the existence of systematic inefficiency in the cost of producing milk. The average inefficiency level of the farmers was 1.044 implying that the observed cost of milk production could be decreased on average by about 4.4 %, without decreasing milk output. The main challenges to the dairy enterprise were the cost of roughages, the small sizes of land owned and the price of labour. Labour productivity was low. Farm inefficiency was not the main cause of high milk production cost. It was recommended that policy makers generate necessary laws and regulations to ensure that the continued land sub-division is reversed and that the cost of dairy farming inputs is reduced. A law on the extent to which agricultural land should be sub-divided requires being enacted. There is a need for reduction on the taxes levied on animal feed-making ingredients. An endeavor to lower the currently high cost of electricity to the average global costs should be made. Improving the road infrastructure could go a long way in lowering the cost of inputs. There is a need for the County governments to provide an enabling environment for fodder commercialization. They could provide public facilities such as fodder harvesting and baling equipments for hire and constructing hay markets where private producers could sell their roughages. An approach that could lead to increased accessibility of dairy farming credit could raise yields and lower the production cost.

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