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Economic efficiency of milk production among small-scale dairy farmers in Mukurweini, Nyeri County, kenya

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This study aimed at evaluating the economic efficiency of milk production among small-scale dairy farmers in Mukurweini, Nyeri County, Kenya. Data were collected from 91 small-scale dairy farmers previously engaged in a nutritional study in 2013. The farmers had been sampled using purposive sampling technique. Data were collected using structured questionnaires, entered into statistical package for social science (SPSS). Stochastic frontier production and cost functions were analyzed using the MLE technique in FRONTIER 4.1. The results showed that farmers were operating at increasing returns to scale of 1.495. The number of lactating cows, amount of concentrates fed to a cow and the cost of animal health controls had a significant effect on milk production, while the production cost was influenced by the costs of fodder, concentrates, animal health and other operating expenses. The mean technical and allocative scores were 0.687 and 0.913 respectively. The milk production could be increased by 31.3% through proper utilization of the available resources such as fodder and concentrates, while the cost of production can be decreased by 8.7% without affecting the output. It was concluded that through efficient use of the available inputs, like the fodder and present technology, economic efficiency would be greatly increased. The study recommends subsidized prices for concentrates.

Key words: Stochastic frontier, milk production, technical, allocative, economic, efficiency.

INTRODUCTION

In Sub-Saharan Africa, Kenya boasts of having the second largest dairy sector in term of milk production and consumption. The country's dairy sector is vigorous and is of great value to the economy of the country as well as the nutrition of the consumers (Wambugu et al., 2011).

According to Muriuki et al. (2004), the dairy sub-sector solely constitutes the greatest proportion of the agricultural sector gross domestic product (GDP) in Kenya and is a source of livelihoods to thousands of households. The sub-sector contributes 14% of the

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agricultural GDP and 3.5% of the country's total GDP (Government of Kenya, 2008). The dairy sector relies majorly on small-scale dairy producers who contribute up to 70% of the total milk in the country (Mawa et al., 2014).

However, small-scale dairy farmers produce 3.67 L of milk per cow daily, on average, a sign that their productivity level is low (Wambugu et al., 2011). This low productivity is attributed to poor feeding, poor animal husbandry, the high cost of production and competitiveness between dairy farming and crop farming (Mawa et al., 2014). Tegemeo Institute (2016) also listed low productivity and high costs of production as the major challenges affecting the dairy industry. With an estimated increase of 3 to 4% per annum in milk consumption as a result of urbanization, increase in population and rise in income, there is need to increase dairy productivity in Kenya (Wambugu et al., 2011).

Mutua (2015) noted that daily milk production per cow was 5.46 L instead of the expected over 12 L. Moreover, MoLD (2010) states that yield per cow has remained at 6 L for over 3 decades although there is a capability of 15 L per cow per day. This is an indication of the inefficiency of the dairy industry. The high cost of inputs coupled with the low productivity could be the source of inefficiencies among the small-scale dairy farmers in the country.

There have been several studies done in the country with the objective of establishing the level of milk production (Ngigi, 2002; Omiti et al., 2006; Staal et al., 2008; Nganga et al., 2010; Mugambi, 2014). However, very few studies have concentrated on establishing the economic efficiency of milk production among the small-scale farmers, considering that the level of milk production has remained low and the cost of production has continued to rise.

Moreover, there has not been any study to assess the economic efficiency of the dairy farmers after the nutritional training by the Canadian organization known as Farmers Helping Farmers in 2013. This study aimed at determining the economic efficiency of milk production among small-scale dairy farmers in Mukurweini, Kenya. By so doing, it will pinpoint some sources of inefficiency and thus provide measures of reducing the inefficiency. The increased milk production will help attain the Malabo Declaration goal of ending hunger by 2025. Moreover, the findings will accentuate factors that will increase farmers' production capacity, hence increasing income and living standards of the rural people.

METHODOLOGY

Study area, sampling technique and collection of data

The study was carried out in Mukurweini sub-County, Nyeri County in Central Kenya in April 2017. The area is located in the south-western part of the county and is known for coffee farming. The reliance on coffee farming has however changed over time, with farmers taking up dairy farming as their main economic activity and there are over 6,000 small-scale dairy farmers in the area. The study focused mainly on primary data that was obtained from farmers sampled using the purposive sampling technique. The farmers had been involved in a two months nutritional training trial in 2013 and were sampled using the purposive sampling technique because they had a newborn dairy calf and recently calved dairy cow (Richards et al., 2016). A total of 111farmers were involved in the 2013 study. However, by the time of this study, some had passed on while others had migrated from the area of study. Thus, only 91 farmers were interviewed in the current study. Semi-structured questionnaires were used to obtain farmer characteristics, farm and cow characteristics and cow feeding information. Data were captured in Statistical Package for the Social Sciences (SPSS) and cleaned. FRONTIER 4.1 was used to determine technical and allocative efficiency scores for each farmer. The product of the technical and allocative efficiency scores yielded economic efficiency scores.

Technical and allocative efficiencies

Efficiency measure can be in terms of output efficiency (the difference between actual and the highest expected output for certain inputs) or input efficiency (the difference between the actual and least expected input for a certain output). Technical efficiency is the capability of a farm to produce a maximum output given various inputs and technology while allocative efficiency is the capability of a farm to assign inputs, given their prices, in a cost-minimizing way (Chukwuji et al., 2006). According to Farrell (1957), a farm operating on the interior of the production iso-quant of a given output is technically inefficient while one operating on the production iso-quant is technically efficient but not necessarily allocatively efficient. A farm is economically efficient if it operates at the point of tangency between the production iso-quant and the iso-cost line for a given output.

Stochastic frontier production and cost function

Aigner et al. (1977) composed the stochastic production frontier model that was used in this study. This model has been used by various studies such as Binam et al. (2004) and Sharma (1999) to assess economic efficiency. The production function as shown in Equation 1 is normally used.

$$Y = f\,(x) \tag{1}$$

The equation for the stochastic production frontier can be written as Equation 2:

$$Y_i = f(X_i;\beta) + \varepsilon_i \tag{2}$$

Where:

$\mathrm{f}(\mathrm{X_i};\beta)$ is a suitable function (Cobb-Douglas or Translog), Y_i is milk production in litres, X_i is the quantity of inputs used in milk production, β is the vector of the unknown parameter to be estimated and ε_i is a random error term made up of the sum of v_i and u_i. v_i is the ordinary two-sided error term assumed to have a mean of zero and constant variance. It captures stochastic effects outside the farmers control, such as weather. u_i is the one-sided error term that accounts for the shortfall from the stochastic frontier.

In order to assess the technical and allocative efficiencies, Cobb-Douglas functional form was taken. It has been used to analyze economic efficiency by Masuku et al. (2014) and Sajjad and Khan (2010). According to Kopp and Smith (1980), Cobb-Douglas

functional form is flexible and self-dual and has reduced empirical efficiency effects.

Empirical models

The Cobb-Douglas production function that was used for obtaining technical efficiency estimates was specified as follows;

$$lnY_i = ln\beta_0 + \beta_1 lnX_{1i} + \beta_2 lnX_{2i} + \beta_3 lnX_{3i} + \beta_4 lnX_{4i} + V_i - U_i \quad (3)$$

Where:

ln= natural logarithm to base 10, Y= Total milk production in litres, X_1= Herd size (number), X_2= Fodder in Kgs, X_3= Concentrates in KgsandX_4= Animal health expenditure (Kshs).

The corresponding Cobb-Douglas cost function used to estimate allocative efficiency was specified as follows;

$$\ln C = \alpha_0 + \alpha_1 lnP_1 + \alpha_2 lnP_2 + \alpha_3 lnP_3 + \alpha_4 lnP_4 + V_i + U_i \quad (4)$$

Where:

ln= natural logarithm to base 10, C=Total cost of milk production, P_1 = Cost of feeds, P_2 = Cost of concentrates, P_3 = Cost of animal health, P_4 =Other operating expenses

Technical and allocative inefficiency effects were defined by;

$$\mu_i = \delta_0 + \delta_1 X_{1i} + \delta_2 X_{2i} + \delta_3 X_{3i} \quad (5)$$

Where:

μ_i = Efficiency score for farmer i, X_1= Age (Years), X_2= Education level of farmer (Years of formal education), X_3= Household family size (Number of members).

These variables were included in the model to show their possible influence on the efficiency of farmers. Maximum likelihood estimation (MLE) procedure in FRONTIER 4.1 was used for the estimation of Equation 3 and 4. These two equations were each individually joint with Equation 5 during the estimation using the program FRONTIER 4.1.

RESULTS AND DISCUSSION

Summary statistics

The summary statistics of variables for the cost and production frontier estimation are presented in Table 1. The mean monthly milk production was found to be 492.69 L with a standard deviation 427.51 L. The large variation in milk production could be associated with the difference in herd sizes and lactation periods of the animals. The mean herd size was 2 cows with a standard deviation of 2 cows. Small-scale farmers are associated with small herds of animals that range between 1 and 4. There was a small variability in the amount of fodder fed per animal (68 kg), an observation that could be attributed to the fact that farmers had attended similar training and workshops on how best to feed their animals. The mean cost of fodder was Kshs6, 954.62 per month. According to the farmers, their spending on fodder had increased during the time of the study as the area was experiencing drought and the prices of purchased fodder had been hiked. According to Daily Nation (2017), farmers are incurring high fodder costs due to the decline in land available for the production of fodder. The cost of concentrates was also relatively high with a mean of Kshs4, 286.26 per month. This result implied that the cost of concentrates in the country is relatively high. The mean age of the farmers was 57 years. The UNDP (2013) reported that the average age of a farmer was 60 years.

Efficiency frequency distribution among small-scale dairy farmers

Table 2 indicates a frequency distribution of technical, allocative and economic efficiencies. The average technical efficiency estimate was found to be 68.7%, suggesting that perhaps a 31.3% loss in milk production was as a result of technical inefficiencies. Similar results were obtained by Nyagaka et al. (2009) in a study of efficiency among Irish potatoes farmers. The allocative efficiency scores had a mean of 91.3%. This finding implies that the farmers were keen on saving the cost of production. The economic efficiency score had a mean of 62.6%. Since economic efficiency is a product of technical and allocative efficiencies, it was noted that the economic inefficiencies were as a result of technical inefficiencies rather than allocative inefficiencies. Similar results were reported by Dipeolu and Akinbode (2008) and Nyagaka et al. (2009). The farmers have the capability of being economically efficient by utilizing the available inputs and technology efficiently (Table 2).

Maximum likelihood estimates of stochastic frontier production function

The maximum likelihood estimates of the specified Cobb-Douglas stochastic production function are presented in Table 3. The variance parameter gamma (0.91) was significantly different from zero, suggesting the existence of inefficiencies among the farmers. The gamma value was significant at 1%, hence the null hypothesis that there was the absence of inefficiencies among the farmers was rejected. The gamma also justified the use of a deterministic method (maximum likelihood) to obtain the efficiency estimates. Since the value (0.91) was close to one, it meant there was limited random noise. The likelihood ratio (LR) value exceeded the critical χ^2 (5%, 1 d.f.) value of 3.84 at 5%, hence the alternative hypothesis was accepted that the Cobb-Douglas form of the data was a good fit.

Table 1. Summary statistics of variables used in the production and cost functions.

Variable	Unit	Median	Mean	Std. deviation	Min	Max
Monthly milk production	Litres	420	492.69	427.51	60	2,460
Herd size	Number	2	2	2	1	17
Monthly fodder/cow	Kgs	1560	1,561.44	68.55	1,424	1,700
Monthly concentrates/cow	Kgs	66	93.06	84.34	84.34	456.01
Monthly cost of animal health	Kshs	216.67	308.85	300.14	16.67	1,700
Cost of concentrates	Kshs	4200	4,286.26	1,760.16	1,010	9,250
Cost of fodder	Kshs	4000	6,954.62	9,515.89	0	45,000
Operating expenses	Kshs	250	3,248.68	11,061.16	50	58,700
Age of household head	Years	55	57.21	12.91	33	87
Education	Years	8	8.88	3.14	0	16
Household size	Number	3	3.57	1.69	0	8

Table 2. Efficiency distributions of small-scale dairy farmers.

Efficiency (%)	Technical efficiency			Allocative efficiency			Economic efficiency		
	No.	Percentage (%)	Cum	No.	Percentage (%)	Cum	No.	Percentage (%)	Cum
91-100	5	5.5	100	67	73.6	100	3	3.3	100
81-90	20	22.0	94.5	14	15.4	26.4	12	13.2	96.7
71-80	18	19.8	72.5	3	3.3	11.0	13	14.3	83.5
61-70	19	20.9	52.7	5	5.5	7.7	22	24.2	69.2
51-60	19	20.9	31.9	1	1.1	2.2	21	23.1	45.1
1-50	10	11.0	11.0	1	1.1	1.1	20	22.0	22.0
Min (%)	39.6	-	-	35.6	-	-	31.2	-	-
Max (%)	95.9	-	-	99.9	-	-	94.9	-	-
Mean (%)	68.7	-	-	91.3	-	-	62.6	-	-

Source: Survey data (2017, n=91).

There was a positive relationship between most of the measured variables and the monthly milk production. The coefficients for the amount of concentrates and cost of animal health were significant at 5% while the herd size coefficient was significant at 1%. Not surprisingly, the herd size was found to be the most influential variable on milk production, as a 1% increase in the number of lactating cows would yield 81% increase in milk production, *ceteris paribus*. This result is congruent to that of Mugambi (2014) who found the herd size to have a great impact on milk production.

Milk production has also been found to be influenced by the amount of concentrate fed to a cow. The results suggest that 1% increase in the amount of concentrate fed to an individual cow was associated with a 9% increase in milk production. Richards et al. (2016) found that an additional 1 kg of dairy meal concentrate fed to a cow per day resulted in an increase of 0.53 kg/cow/day in milk output. The difference in the results considering the two studies involved the same sample of farmers could be attributed to the cow's lactation period. Richards et al. (2015) focused on cows in early lactation where milk production is associated with the amount of concentrates fed to a cow, while this study was not specific on the lactation period. Cows in mid or late lactation periods are less sensitive to the amount of concentrates fed to them.

There was also a positive relationship between animal health costs and milk production. A farmer incurring animal health costs represented that the farmer dewormed and treated the animals when ill, which should lead to better milk production. A study by Sanchez et al. (2004) indicated that healthy animals tend to have better milk production. Another study by VanLeeuwen et al. (2012) reported that improved cattle health among dairy farmers in Mukurweini resulted in an increase in milk production.

In the inefficiency model, farmer's age was found to be statistically significant at 5%. This implies that as farmers grow old, they become less efficient. This result is consistent with Sajjad and Khan (2010) who found farmer's age to have a positive influence on inefficiency. The returns-to-scale (RTS) was found to be 1.5, implying that farmers were operating at stage one (I) of production. This stage is usually characterized by inefficiency as it

Table 3. Maximum likelihood estimates of the stochastic frontier production function.

Variable	Parameter	Maximum Likelihood estimates		
		Coefficient	Standard error	*t*-ratio
Constant	β_0	0.8975	3.9268	0.2286
LnHerdsize	β_1	0.8129***	0.1278	6.3628
LnFodder	β_2	0.4303	1.2323	0.3492
LnConcentrates	β_3	0.0949**	0.004	2.4042
LnAnimalhealth	β_4	0.1571**	0.0616	2.5515
Inefficiency model				
Constant	δ_0	-0.1589	0.3359	-0.4733
Age	δ_1	0.0098**	0.0036	2.7518
Years of education	δ_2	-0.0067	0.0114	-0.5845
Size of household	δ_3	0.0034	0.0231	0.1459
Variance				
Sigma square	δ^2	0.0688***	0.0178	3.8712
Gamma	γ	0.9082***	0.0943	9.6298
Log-likelihood function	LH	7.4289	-	-
Log Likelihood ratio	LR	18.47	-	-

Asterisks show significance at the following levels: **5%; ***1%.
Source: Survey data (2017, n=91).

exhibits increasing returns to scale. At this stage, in the short run, an increase in the input would yield more than the proportionate increase in the output.

Maximum likelihood estimates of stochastic frontier cost function

The likelihood ratio (110.74) justified the use of maximum likelihood estimates rather than ordinary least square (OLS) estimates. Also, since its value was greater than the Kodde and Palm critical value of 10.37 for 5 degrees of freedom, the null hypothesis that stated that the farmers were allocatively efficient was rejected. The gamma value showed that 99% of the total variance was due to inefficiencies (Table 4).

A mean of 1.1237in the allocative inefficiency was an indication that 12.4% of costs were associated with inefficiency. Dividing the percentage base of allocative efficiency (which was 100) by the allocative inefficiency value yields the allocative efficiency score. In this study, the mean allocative efficiency score was found to be 89%. The coefficients of all the variables used in the final cost model were significant at 1%. The cost of feeds coefficient had the greatest magnitude of 0.468, which could be attributed to the fact that, due to the drought, many farmers were relying on purchased feeds whose prices had been hiked by the sellers. The coefficient of costs of concentrates (46%) was also quite high and significant. Mbilu (2015) found that cost of concentrates accounted for 45% of the total variable costs in dairy production. The magnitude of operating expenses could vary from time-to-time, depending on repairs and maintenance and purchases made by an individual farmer. A 1% increase in these expenses was estimated to result in a 5% increase in total cost of production *ceteris paribus*.

The coefficient of the intercept in the inefficiency model was negative and significant, suggesting that there were other variables not included in the model that would significantly lower the inefficiency. Years of education and size of household coefficients were found to be positive and significant at 1%; an increase in either of them would result in a rise of allocative inefficiency.

CONCLUSION AND RECOMMENDATIONS

The mean economic efficiency of 62.6% revealed that farmers in the study area had potential to increase their economic efficiency by 37.4%, thus increasing their milk output. The results further indicated that the economic inefficiency that the farmers were experiencing was primarily because of inefficient use of the available inputs and technology. The high mean allocative efficiency score of 91.3% shows that farmers are capable of minimizing costs, thus allocative inefficiency is not a problem among the farmers. Increase in herd size, amount of concentrates and having healthy animals would result in an increase in monthly farm-level milk

Table 4. Maximum likelihood estimates of the stochastic frontier cost function.

Variable	Parameter	Maximum likelihood estimates		
		Coefficient	Standard error	*t*-ratio
Constant	β_0	0.3868***	0.0078	49.836
LnFeedcost	β_1	0.4683***	0.0084	55.481
LnConcentratecost	β_2	0.467***	0.0043	108.68
LnAnimalhealth	β_3	0.0256***	0.0020	12.614
LnOperatingcost	β_4	0.0467***	0.0043	10.906
Inefficiency model				
Constant	δ_0	-2.5824***	0.6715	-3.8457
Age	δ_1	0.0037	0.0096	0.3872
Years of education	δ_2	0.0775***	0.0134	5.8009
Size of household	δ_3	0.2459***	0.0243	10.101
Variance				
Sigma square	δ^2	0.0812***	0.0094	8.615
Gamma	γ	0.999***	0.0000	565459
Log-likelihood function	LH	122.86	-	-
Log Likelihood ratio	LR	110.74	-	-

Asterisks show significance at the following levels: **5%; ***1%.
Source: Survey data (2017, n=91).

output. Since the farmers have increasing returns-to-scale, an increase in these current inputs would yield more than the proportionate increase in the milk production in the short-run.

The cost of fodder and concentrates constitute a high percentage of the total variable cost. The high cost of fodder could be attributed to the hiked prices due to drought as well as the small land sizes owned by farmers. Having small pieces of land leads to an increase in the demand for fodder as farmers have no enough space to grow their fodder. The drought coupled with small land sizes brings about high demand for fodder leading to high prices. Thus, farmers should be facilitated by other stakeholders (County and National governments, NGOs, etc.) to grow drought-tolerant leguminous shrubs (such as Calliandra) and/or store adequate fodder for such situations. For instance, they should construct silage bunkers, pits or tubes and store fodder in bulk during the seasons when fodder is plentiful.

The farmers could also be trained on means of intercropping their fodder with other food crops they grow as well as the new technologies of growing fodder on limited spaces such as hydroponic fodder technology. The government should find means of subsidizing the highly priced concentrates to make them affordable to capital-poor farmers. The youth should be sensitized to engage in dairy farming seeing that inefficiency was higher with older ages. The sensitization could be through better returns for the dairy sector and conducive policy environment. The older farmers could also be sensitized to adopt the new technologies in dairy farming through training, farmer exhibitions and farmer-to-farmer learning. All these findings will enable the policymakers to come up with policies aimed at increasing the small-scale dairy farmers' economic efficiency which will in-turn help improve nutrition and achieve food security.

CONFLICT OF INTERESTS

The sources of funding had no conflicting interest in this research and were not involved in data collection, data analysis and publication.

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