academicJournals

Vol. 6(11), pp. 455-465, November, 2014
DOI: 10.5897/JDAE2014.0561
ISSN 2006-9774 ©2014.
Article Number: 73E8B2848136

http://www.academicjournals.org/JDAE

Journal of Development and Agricultural Economics

Full Length Research Paper

Profit efficiency of dairy farmers in Kenya: An application to smallholder farmers in Rift Valley and Central Province

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Received 21 January, 2014; Accepted 20 August, 2014

The dairy industry in Kenya is an important source of livelihood among the smallholder farmers who supply over 70% of the total milk. However, there is a growing concern on rising costs of milk production among farmers. The study assessed profit efficiency of smallholder dairying in the Rift Valley and Central Provinces of Kenya using stochastic frontier analysis for estimating farm level profit efficiency and identifying the specific determinants of efficiency. The results showed that the farmers are fairly profit efficient with an average of about 68%. Cost of fodder produced on farm significantly improved profit efficiency among farmers. However dairy profit efficiency can be enhanced if fodder production is embraced, as well as other supplemental feed technologies that are commensurate with local conditions. Institutional policy reforms on smallholder dairying will help protect the industry and its sustainability for smallholders.

Key words: Dairy, profit efficiency, stochastic frontier, smallholder farmer.

INTRODUCTION

Kenya is the second largest dairy producer and consumer in sub-Sahara Africa and is relatively self-reliant (USAID, 2010). About 60% of the total milk production in Kenya is produced by farmers in the Rift Valley and Central Province who own about 80% of the exotic and cross-breed cattle (Omore et al., 1999). Previous studies have identified that smallholder farmers supply over 70% of the total milk, mainly from cattle, but some little quantities from camels and goats (USAID, 2008; Muriuki, 2003). Smallholder dairying is a potential contributor of income and employment generation both on-farm and off-farm, as well as improved nutrition of households (Staal et al., 2008; USAID, 2010). At the macro level, the dairy industry contributes an estimated 14% of agricultural gross domestic product (GDP) and approximately 4% of overall Kenya's national GDP (USAID, 2010). It is anticipated that the demand for milk is likely to double due to the growing world population

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(FAO, 2011, 2003). Despite the demand prospects, farmers and stakeholders have increasingly expressed concern over the growing costs of milk production which ultimately result in diminishing milk profits in Kenya. FAO (2003) reported that there is competition for land, water and other environmental resources due to the increasing population. It is apparently plausible that these constraints are shifting farmers' practices from traditional pasture grazed systems to intensive production technologies which are often more expensive than extensive systems. This study proposed to assess profit efficiency of smallholder dairy production and identify its determinants among farmers in the Rift Valley and Central Provinces using Stochastic Frontier approach (SFA). Profit efficiency is a wider concept than cost efficiency since it takes into account the effects of the choice of a certain vector of production both on costs and on revenues, thus offering complementary information useful for the analysis of dairy farm efficiency.

METHODOLOGY

Theoretical framework

Stochastic production frontier models were introduced by Aigner et al. (1977) and Meensen and van den Broeck (1977). Battese and Coelli (1995) and Coelli (1996), extended the stochastic production frontier model, suggesting that the inefficiency effects can be expressed as a linear function of explanatory variables, reflecting farm-specific characteristics. Farm level inefficiency measurements are common among researchers (Kumbhakar et al., 1989; Wang et al., 1996; Abdulai and Huffman, 2000; Rahman, 2003). The advantage of the stochastic frontier model is that it allows estimation of farm specific efficiency scores and the factors explaining efficiency differentials among farms in a single stage estimation procedure. Three common efficiency measures include Technical efficiency, Allocative efficiency and Economic efficiency. However, the profit efficiency measure combines the concepts of Technical and Allocative efficiencies into the profit relationship and as such any errors in the production decision are assumed to be translated into lower profits or revenue for the producer (Ali et al., 1994). Kumbhakar and Lovell (2000) provided a detailed account of stochastic frontier models. Accordingly, the stochastic frontier function is defined by Equation 1 as follows:

$$\prod = f\,(P_{ij}, Z_{ik})\, \exp(\varepsilon) \qquad (1)$$

The error term, $\varepsilon_i = v_{i\_}u_i$, is assumed to behave in a manner consistent with the stochastic frontier concept (Ali and Flinn, 1989)

Where:

$\prod$ = normalized profit of the i^{th} firm;

P_{ij} = price of j^{th} variable input faced by the i^{th} farm divided by output price;

Z_{ik} = level of the k^{th} fixed factor on the i^{th} firm.

v_i is assumed to be identically and normally distributed with mean zero and constant variance as:

$N\,(0, \sigma_v^2)$.

u_i is the one-sided disturbance form representing profit inefficiency and it is independent of v_i;

and i = 1,2 ….., n, representing the individual firms.

Profit efficiency of the i^{th} firm can be presented as:

$$\mathrm{EFF} = E[\exp(-u_i)/\varepsilon_i] = E[\exp(-\delta_0 - \textstyle\sum_{d=1}^{D} \delta_d W_{di})/\,\varepsilon_i] \qquad (2)$$

Where:

E = expectation operator, which is achieved by obtaining the expressions for the conditional expectation u_i upon the observed value of ε_i;

W_{di} = d^{th} explanatory variable associated with inefficiencies on firm i.

δ_0 and δ_d = unknown parameters jointly estimated using the maximum likelihood method with the stochastic frontier and the inefficiency effects functions simultaneously.

The likelihood function is expressed in terms of the variance parameters: sigma squared;

(σ^2) = σ_v^2 - σ_u^2 and; gamma (γ) = $\frac{\sigma_u^2}{\sigma^2}$ (Battese and Coelli 1995).

The parameter γ represents the share of inefficiency in the overall residual variance with values in the interval of 0 and 1. A value of 1 suggests the existence of a deterministic frontier, whereas a value of 0 can be seen as evidence in the favor of ordinary least square (OLS) estimation.

Specification of the empirical model

Profit efficiency is defined as the gain from operating on the profit frontier, while taking into account farm-specific prices faced and factor endowments. Assuming a farm that maximizes profit is operating in a perfectly competitive input and output markets and uses a singular output technology, the actual normalized profit function is derived as:

$$\mathrm{GM}(\prod) = \mathrm{TR} - \mathrm{TVC} = PQ - WX_i \qquad (3)$$

Where: GM = Gross margin; TR = total revenue; TVC = total variable cost - (as opposed to fixed costs as they remain fixed whether or not production has taken place, and to what scale production has been). Normalizing the profit function is achieved by dividing both sides of Equation 3 by the output market price, that is:

$$\frac{\Pi(p,z)}{p} = \sum \frac{(PQ - WX_i)}{p} = \frac{PQ - WX_i}{p} = f(X_i, Z)\sum P_i X_i \qquad (4)$$

Where: - $f\,(X_i, Z)$ is the production function.

The profit function in implicit form which specifies efficiency is expressed as:

$$\prod = f\,(P_{ij}, Z_{ik})\, \exp\,(v_i - u_i) \qquad (5)$$

I = 1,2,3…………..n represent the individual firms.

The profit efficiency is expressed as the ratio of predicted profit to the predicted maximum profit for a best firm and is expressed as:

$$\text{Profit efficiency } (E\prod) = \frac{\Pi}{\Pi_{max}} = \frac{\exp[\prod(p,z)]\exp(\ln v)\exp(\ln u)\theta}{\exp[\prod(p,z)]\exp(\ln v)} \qquad (6)$$

Firm specific profit efficiency is again the mean of the conditional distribution of u_i given by $E\prod$ and is defined as:

$$E\prod = E\left[\frac{\exp(\ln u_i)}{E_i}\right] \qquad (7)$$

$E\prod$ takes the value between 0 and 1.

If u_i is = 0, that is, on the frontier, the firm is obtaining potential maximum profit given the price it faces and the level of fixed factors. If u_i > 0, the firm is inefficient and losses profit as a result of inefficiency. The inefficiency effect model can only be estimated if the efficiency effects are present. Given that u_i is present in the model it implies that it is justifiable to employ the SFA as similarly argued by Aneani et al. (2011). In this study, Battesse and Coelli (1995) and Coelli (1996) models were used to specify the stochastic frontier function with behavior inefficiency components and used to estimate all parameters together in one step maximum likelihood estimation.

Different functional forms have been used by scholars for measuring firm level efficiency, namely the Cobb-Douglas function, normalized quadratic, normalized translog and generalized Leontif, but the commonly used forms are the Cobb-Douglas and Translog forms. A detailed literature is presented by Abdulai and Huffman (2000) on the weaknesses of the two functional forms. It is argued that the Cobb-Douglas form is restrictive compared to the more flexible functional forms such as the translog and quadratic forms. Upton (1979) also added that the Cobb-Douglas function cannot show both increasing and diminishing marginal productivity in a single response curve. As a result it does not give a technical optimum and may lead to the over estimation of the economic optimum. An ideal option would be the translog. However, the drawbacks of the translog model are that it has potential problems of insufficient degrees of freedom due to the presence of interaction terms; even though such interaction terms do have important economic implications and meaning (Abdulai and Huffman, 2000). Scholars such as Ọlayide and Heady (1982) used the quadratic function to measure the direct effects of inputs on output. However, the transcendental function and the quadratic functional models seem unpopular among researchers due to limited application.

Despite the restrictive nature of the Cobb-Douglas function, many scholars and researchers have found it relevant, especially when there are many variables in the model (Taru et al., 2011; Ojo et al., 2006; Rahman, 2003; Ekpebu, 2002; Abdulai and Huffman, 2000; Saleem, 1988; Kalirajan and Obwona, 1994; Dawson and Lingard, 1991; Yilma, 1996; Nsanzugwanko et al., 1996; Battese and Hassan, 1999). Ekpebu (2002) on the other hand argued that the Cobb-Douglas functional form is useful in analysis of surveys where many variable inputs are involved and it is necessary to measure returns to scale, intensity of factors of production and overall efficiency of production. It is also argued that it provides a means of obtaining coefficients for testing hypotheses (Cobb and Douglas, 1928; Erhabor, 1982). Akighir and Shabu (2011) cited Ellebu, Koku and Ogidi (2004) that the evidence of the superiority of Cobb-Douglas functional form is supported by its satisfaction of the economic, statistical and econometric criteria required unlike the other functional forms.

In view of the above arguments, the Cobb-Douglas functional form was applied for estimating dairy profit efficiency of the smallholder farmers in the study area, whose empirical model is specified below. However, for comparison purposes, the translog, quadratic and transcendental forms were equally applied (though their empirical models have not been specified here).

The explicit Cobb-Douglas functional model for this study is specified as follows:

$$\ln \pi_i = \alpha_0 + \alpha_1 \ln Z_{1i} + \beta_k \sum_{k=1}^{12} \ln P_{ki} + (v_i - u_i) \tag{8}$$

Where π is the normalized profit computed as total milk revenue per litre less variable cost per litre divided by farm specific milk price per litre; α and *β* represent the individual variable coefficients in the stochastic frontier model; *Z* is the total number of cows on the farm; *P*s represent the cost of production inputs per unit of each respective input (that is, P_{1i} = artificial insemination price per cow, P_{2i} = price of veterinary services per administration, P_{3i}= price of extension services per visit, P_{4i} = monthly labor wage, P_{5i} = purchase fodder price per kilogram (kg), P_{6i} = imputed price of produced fodder per kg, P_{7i} = price of dairy concentrates per kg, P_{8i}= price of conserved feeds per kg, P_{9i} = grazing price per cow, P_{10i} = price of water per litre, P_{11i} = price of milk transport (per litre), P_{12i} = price of milk (per litre) for feeding calves. $(v_i - u_i)$ is the composed error term.

The inefficiency model (u_i) is defined by the equation as follows:

$$u_i = \delta_0 + \sum_{z=1}^{12} \delta_z T_z \tag{9}$$

Where *δ* represent the respective regressor coefficients; *T*s represent farm, household and institutional socioeconomic characteristics (that is, T_1 = age of farm owner, T_2 = size of fodder land, T_3 = size of grazing land, T_4 = hourly wage rate, T_5 = production system(dummy), T_6 = production scale(dummy), T_7 = gender of farm owner (dummy), T_8 = hired labor(dummy), T_9 = extension service access (dummy), T_{10} = paid extension service (dummy), T_{11} = paid water (dummy), T_{12} = rented land (dummy).

Data and variables measurement

The study was conducted in Kenya's Rift Valley and Central Provinces where the East Africa Dairy Development (EADD) project has earmarked interventions, excluding the pastorally dominant cattle keeping communities. Data was collected from smallholder dairy farmers using structured household questionnaires. Details of production costs and revenues generated from milk in the past 3 months from the date of interview (August, 2012) were identified. This was to ensure accurate recall of production situations by the farmer, which is highly unlikely for an entire annual period due to lack of record keeping as argued by Staal et al. (2008). Detailed data was collected on feeds and their sources, other inputs used in production, the costs involved in acquiring these inputs and related services accessed by the farmer. Additionally, the amount of milk obtained from lactating cows and the revenues generated were obtained. Milk that was consumed by the farm families, milk fed to calves and milk given to family friends/neighbors were valued at the cost price, while that sold was valued at the going market price of the respective channels. The gross profit of milk was used as the main outcome variable. The cost determinants and inefficiency factors in the frontier model were then examined against the outcome variable as earlier specified. Multistage sampling procedure was used to select a representative number of farmers into the study. Farmers were stratified according to the main production system that is, mainly extensive or intensive system. A further stratification was based on the production scale that is, small-scale and medium-scale, assigned according to the number of cows managed under the respective production systems. These were arrived at based on the EADD precept for categorizing production scales of the smallholder farmers based on the baseline data for Rwanda, Uganda and Kenya (Table 1).

The study sample size was computed using the formula (Equation 10) for obtaining sample sizes of each group for comparison in the study (if the outcome variable is a continuous univariate data). An assumption of this study was that unit profits among the farmers is a continuous variation and follows a normal distribution pattern, varied unit costs, herd sizes, production systems, parity differences of lactating cows, and management efficiency differences across farms, to mention but a few.

$$n = 2 \times \frac{\left(Z_{\frac{\alpha}{2}} + Z_{\beta}\right)^2}{d^2} \sigma^2 \tag{10}$$

Where: n = approximate sample size; d = margin of error (mean unit profit difference between the 2 groups, mean ± d = confidence interval) (assumed at 0.1); σ^2 = assumed std deviation of 0.2 for unit profit; $Z_{\alpha/2}$ = 1.96 signifying a 2-sided sample size at 95% confidence level; Z_{β} = power of the test in identifying a significant difference (that is, 'chance' of this happening - 80%)

Table 1. Production scales per production system**.**

Production scale	Production system	
	Intensive	Extensive
Small-scale	≤ 3 Cows	≤ 15 Cows
Medium-scale	≥ 4 Cows	≥ 16 Cows

Source: EADD Field Survey (2009).

A total of 122 farmers (half for intensive and half for extensive production systems) were therefore approximated to be an adequate representative sample for the study. However, there were relatively fewer numbers of intensive farms identified during the field data collection process. Hence, only a total of 85 farmers were therefore ultimately surveyed.

EMPIRICAL RESULTS AND DISCUSSION

Descriptive summaries

Table 2 shows the descriptive summaries of the variables that were structured in the study questionnaire. The study found that the average number of cows owned per farm is 3 with a standard deviation of 2.0. The average land size under fodder production was found to be 2.3 acres with a standard deviation of 2.2, while that of grazing land was 6.0 acres with a high standard deviation of 52.4.

The proportion of farmers practicing extensive system was only 27% of the total farmers. This is mainly attributed to the competitive use of land resources influenced by the rising population (FAO, 2003). It was found that the intensive farms incurred higher production costs than the extensive farms on average. This difference was mainly attributed to feed costs and labour expenses incurred in intensive systems than extensive systems. The average total cost of milk production incurred per household in the past 3 months was Kshs 41,070, while total revenue amounted to Kshs 42,210. The average household milk produced in 3 months amounted to 1617 L, while the average total milk sold was 1100 L. Households also consumed about 520 L at home on average. Feed costs constituted the greater proportion of farmers' cost of milk production. Among the cost components, fodder produced on farm constituted the greater proportion of variable costs with an average of Kshs 23,000. The average amount of milk produced by households was 1,617 L though with a high standard deviation. This variation was mainly attributed to the number of cows in lactation, varying lactation lengths and parity effects, among others.

In terms of marketing of milk outputs, majority of farmers sold a greater portion of milk to the Chilling Plants (CPs) (local fresh milk buying centers) in the past 3 months amounting to 930 L on average. The least quantity was sold to private traders (35 L). Although the study did not prioritize producer choice for market channels, the preference for CPs by farmers would be largely attributed to a couple of factors, despite the lower prices offered by this channel. These could range from: a) the capability and the reliability of CPs to buy and pay for every quantity supplied compared to small scale traders and individual consumers; b) the relatively stable prices offered by CPs; c) the input incentives and extension services by some CPs to farmers on contractual terms; d) the belonging of some of the farmers' to the cooperatives owning these CPs. Overall, the average household revenue earned in a quarter of a year from milk amounted to Kshs 42,000. The revenue from direct milk sales approximated to Kshs 29,000 and that of unsold milk amounted to KShs13,000 (Table 2).

Table 3 presents a summary statistics of the normalized unit variable costs and gross margin per liter of milk in the stochastic frontier model. Generally, the cost of feeds constituted the greater proportion of cost of milk production. The average cost of fodder production amounted to Kshs 0.74. This was followed by cost of labour and conserved feeds (Kshs 0.20, respectively). Among the feed costs, the cost of grazing was the cheapest (Kshs 0.10). Overall, the average cost of milk transport was the least of all the variable costs (Kshs 0.03). The normalized average gross margin per litre of milk amounted to Kshs 0.62.

Smallholder dairy profit efficiency in Kenya

Table 4 shows the stochastic model estimation results for the four functional forms: Cobb-Douglas, translog, quadratic and transcendental forms. The results showed that the average profit efficiency estimated by the Cobb-Douglas functional model was 68%. Compared to the other functional forms, the quadratic function estimated a similar mean efficiency (68%). The translog form estimated an average efficiency of 67%, while the transcendental form estimated an average of 71% (Table 4).

The likelihood ratio test was used to compare between the functional forms. The translog form was taken as the unrestricted log likelihood function (ULLF) and the rest as the restricted log likelihood functions (RLLF) since the coefficient estimates of some variables were hypothesized to be 0. The test statistic used to determine whether there was any difference between the translog function and any one of the other forms was:

Table 2. Summary statistics of variables used in the stochastic frontier model.

Variable Name	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum	Standard deviation
Physical inputs							
No. of cows on farm	1.0	2.0	3.0	3.3	4.0	11.0	2.0
No. of hired labour	0.0	0.0	0.0	0.5	1.0	2.0	0.6
No. of household labour	0.0	2.0	3.0	2.6	3.0	7.0	1.5
Acres of fodder	0.0	0.6	1.5	2.3	3.4	10.0	2.2
Acres of grazing land	0.0	0.0	0.0	6.0	0.0	500.0	52.4
Variable costs							
Breeding	0.0	0.0	500.0	950.6	1300.0	10500.0	1608.4
Health	0.0	935.0	1990.0	2394.0	3190.0	9560.0	2015.0
Extension	0.0	0.0	0.0	102.3	0.0	1500.0	318.4
Hired labour	0.0	0.0	0.0	3551.0	6000.0	15000.0	4553.2
Purchased fodder	0.0	0.0	0.0	1004 .0	0.0	44000.0	4910.7
Concentrates	0.0	1673.0	2600.0	3745.0	5530.0	17120.0	3619.6
Farm produced fodder	0.0	5500.0	15000.0	23000.0	34380.0	100000.0	22444.6
Conserved feeds/forage	0.0	0.0	0.0	1248.0	0.0	22950.0	3782.9
Grazing	0.0	0.0	0.0	682.4	0.0	9000.0	1756.3
Water	0.0	0.0	0.0	216.9	0.0	13500.0	1468.6
Transport	0.0	0.0	180.0	596.6	967.5	4500.0	882.7
Milk to calves	0.0	0.0	0.0	2298.0	2866.0	22240.0	4488.3
Total variable costs	**1600.0**	**16100.0**	**32020.0**	**38610.0**	**51490.0**	**174400.0**	**30084.7**
Fixed costs							
Depreciation	14.7	182.8	544.0	1458.0	1799.0	9729.0	2008.7
Household labour	0.0	668.9	1698.0	2209.0	3307.0	15790.0	2262.4
Total fixed costs	14.7	282.6	1618.0	2465.0	4379.0	14050.0	2771.4
Total cost	**2078.0**	**16620.0**	**33920.0**	**41070.0**	**57770.0**	**177900.0**	**31299.0**
Milk sales							
Qty sold to Chilling plant	0.0	450.0	697.5	930.3	1080.0	4230.0	831.7
Qty sold to Individuals	0.0	0.0	0.0	128.7	180.0	1080.0	236.1
Qty sold to Private traders	0.0	0.0	0.0	34.5	0.0	990.0	148.8
Total quantity sold	**0.0**	**540.0**	**855.0**	**1094.0**	**1508.0**	**4230.0**	**877.7**
Price							
Unit price - Chilling plant	22.0	24.0	26.0	26.1	27.0	32.0	*
Unit price - individuals	20.0	25.9	30.0	28.9	30.0	60.0	*
Unit price - private traders	10.0	24.8	25.5	26.8	30.5	39.0	*
Milk price	**21.0**	**25.0**	**27.0**	**26.7**	**28.6**	**32.0**	**2.4**
Quantity							
Quantity fed to calves	0.0	0.0	0.0	101.0	168.8	1350.0	211.0
Quantity consumed at home	0.0	180.0	270.0	317.6	360.0	1080.0	211.0
Quantity offered to workers	0.0	0.0	0.0	104.7	0.0	2700.0	426.4
Total quantity unsold	**0.0**	**202.5**	**360.0**	**523.3**	**607.5**	**3510.0**	**578.1**
Milk revenue							
Total milk output	**180.0**	**821.2**	**1260.0**	**1617.0**	**2205.0**	**6210.0**	**1240.2**
Total revenue (sold milk)	0.0	14580.0	22070.0	29170.0	39760.0	127400.0	24171.6
Total revenue (unsold milk)	0.0	4840.0	9511.0	13040.0	18380.0	50600.0	11774.0
Total milk revenue	5890.0	24130.0	35550.0	42210.0	53690.0	157500.0	27779. 7

Source: EADD field survey (2012).

Table 3. Descriptive statistics of variable costs (Kshs) in the stochastic frontier model.

Variable	Frequency	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum
Breeding	45	0.01	0.03	0.04	0.05	0.06	0.19
Health	78	0.00	0.04	0.06	0.08	0.10	0.37
Extension	8	0.01	0.02	0.03	0.04	0.07	0.11
Labour	41	0.03	0.08	0.13	0.20	0.28	0.83
Purchased fodder	12	0.01	0.03	0.08	0.12	0.15	0.56
Produced fodder	69	0.04	0.26	0.60	0.74	1.15	3.70
Concentrate	74	0.00	0.05	0.11	0.13	0.16	0.60
Conserved feeds	20	0.00	0.03	0.07	0.20	0.31	0.90
Grazing	17	0.00	0.05	0.07	0.10	0.12	0.28
Water	7	0.01	0.01	0.02	0.06	0.04	0.31
Transport	48	0.00	0.01	0.02	0.03	0.04	0.07
Calf milk	25	0.05	0.10	0.12	0.13	0.15	0.33
Gross margin	85	-0.10	0.45	0.62	0.62	0.75	1.86

Source: EADD field survey, August (2012).

$$\lambda = 2(ULLF - RLLF) \tag{11}$$

The test statistic λ follows the Chi-square (χ^2) distribution with degrees of freedom (df) equal to the number of restrictions imposed by the null hypothesis on the RLLF. Equation 11 was used to compute λ from the log likelihood values of the estimated functional forms in Table 4. If the *apriori* restrictions are valid, the restricted and the unrestricted (log) LF should not be different, in which case λ will be 0. But if that is not the case, the two LFs will diverge. The hypothesis tested was that the translog function was not different from the Cobb-Douglas function (where λ = 72.6598 and df = 32), the quadratic function (where λ = 18.3322 and df = 8), the transcendental function (where λ = 16.0474 and df = 21). The statistics calculator was then used to compute the p-values for the Chi-square test of the given Chi-square values and the df. The respective computed p-values were 0.0000, 0.0189 and 0.7156. The results showed that the translog function was statistically significant from the Cobb-Douglas function (p-value = 0.000) and the quadratic function (p-value = 0.0189); leading to the conclusion that the restrictions should not have been imposed. However, there was no difference between the translog and the transcendental functions (p-value = 0.7156).

As alluded to the earlier discussion, each of the functional forms has strengths and weaknesses. Nevertheless, scholars and researchers have found the Cobb-Douglas functional form useful in analysis of surveys where many variable inputs are involved like in this study. In spite of restrictions, the superiority of the Cobb-Douglas functional form in the results is supported by its satisfaction of the economic, statistical and econometric criteria required unlike the other functional forms. A panoramic view over the results of the models gives the impression that the Cobb-Douglas functional form resonates with and underscores the significance of the socioeconomic and institutional factors better than the other functional forms. Hence, the Cobb-Douglas functional model output was adopted for further discussion of the study findings.

The study found that the specified stochastic frontier model was adequate in estimating profit efficiency, in that the variance parameter, sigma-squared (0.86), was statistically significant (p-value < 0.001). This implied that the composed error term ($\varepsilon = v_i - u_i$) strongly dominated the measurement error. The gamma value of 0.91 was also found to be significant. A value of 1 would suggest a deterministic approach for the efficiency estimates since there is no random noise, while a value of 0 would mean OLS model is a best estimator because there is no inefficiency. A variance ratio (γ^*)[1] of 0.79 was computed, implying that 79% of the differences in actual and the observed frontier efficiency is attributable to the farmers inefficient practices. Additionally the null hypothesis (H_0: $\gamma = 0$); specifying that the inefficiency effects in the stochastic frontier are not stochastic was rejected because the value of gamma is significantly different from 0 (p-value < 0.001). Further evidence of "goodness of fit" of the stochastic frontier model was proven by the likelihood ratio test (Table 4) with a significant p-value (<0.001), signifying that the stochastic frontier model was a better estimator of profit efficiency in this study than the traditional OLS model.

The estimated coefficients of the Cobb-Douglas function can best be explained as the elasticity of the respective variables. As argued by Abdulai and Eberlin (2001) the first-order coefficients of the functional forms are of less significance in interpreting the outputs of the model because they are not very informative, but rather

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[1] $\gamma^* = \gamma / [\gamma + (1 - \gamma)\pi/(\pi - 2)]$ (Coelli et al., 1998)

Table 4. Profit efficiency estimates of the respective functional forms.

Variable name	Parameter	Cobb-Douglas	Translog	Quadratic	Transcendental
Stochastic frontier model					
Intercept	β_0	-1.6511***	-2.9966***	-0.6766	0.6755
ln Cows (size on farm)	β_1	0.0021	0.5325*	-0.2048	-0.2780
ln Breeding	β_2	-0.0175	0.0164	0.0033	-0.0068
ln Health	β_3	-0.0005	-0.1733	-0.0417	-0.0233
ln Extension	β_4	-0.0043	-0.2497**	-0.0715.	0.0009
ln labour	β_5	-0.0057	-0.0291	0.0084	-0.0106
ln Fodder purchased	β_6	-0.0521***	0.0712	-0.0474*	0.0134
ln Produced fodder	β_7	0.0902***	1.3983***	0.1035***	0.0743***
ln Concentrates	β_8	-0.0056	-0.1756*	0.0410	0.0171
ln Conserved feeds	β_9	-0.0390***	0.0694	0.0454	0.0299
ln Grazing	β_{10}	-0.0144	-0.0249	-0.0021	-0.0283
ln Water	β_{11}	-0.0385*	0.1380	0.0875	0.0204
ln Transport	β_{12}	-0.0280***	-0.0232	-0.0798*	-0.0494*
ln Calf milk	β_{13}	-0.0121	-0.1612***	-0.0973*	-0.0070
ln Cows (size on farm) squared	β_{14}		-0.5474**	-0.0244	
ln Breeding squared	β_{15}		0.1056*	-0.0191	
ln Health squared	β_{16}		-0.0339	-0.0302	
ln Extension squared	β_{17}		-0.4671**	-0.1885	
ln Labour squared	β_{18}		-0.0444	0.0292	
ln Fodder purchased squared	β_{19}		0.3257***	0.0194	
ln Produced fodder squared	β_{20}		0.0979*	0.0352*	
ln Concentrates squared	β_{21}		0.0507***	0.0308 *	
ln Conserved feeds squared	β_{22}		0.1529*	0.0882	
ln Grazing squared	β_{23}		0.0041	0.0081	
ln Water squared	β_{24}		0.5899***	0.2915	
ln Transport squared	β_{25}		0.0828	-0.1473*	
ln Calf milk squared	β_{26}		-0.2425*	-0.1230.	
ln Breeding * ln Extension	β_{27}		-0.0069***		
ln Breeding * ln Health	β_{28}		0.0091		
ln Fodder purchase * ln fodder Produced	β_{29}		-0.1255***		
ln Fodder Produced *ln Concentrates	β_{30}		-0.0141.		
ln Cows* ln Labour	β_{31}		0.0215*		
ln Health * ln Concentrates	β_{32}		0.0080		
ln Cows * ln Health	β_{33}		0.0504*		
ln Cows* ln fodder produced	β_{34}		0.1230		
Cows (total number on farm)	β_{35}				0.0030
Breeding	β_{36}				-0.0570
Health	β_{37}				0.1705
Extension	β_{38}				-0.0582
Labour	β_{39}				0.0774
Fodder purchased	β_{40}				-5.5331***
Fodder produced	β_{41}				0.0215
Concentrates	β_{42}				-0.2885
Conserved feeds	β_{43}				-0.2920
Grazing	β_{44}				-0.0025
Water	β_{45}				-1.9768*
Transport	β_{46}				0.8178
Calf milk	β_{47}				-0.1616
Breeding * extension	β_{48}				0.1281
Breeding * health	β_{49}				-0.0157

Table 4. Contd.

Fodder purchased* produced fodder	β_{50}				0.7646***
Produced fodder * concentrates	β_{51}				10.1260
Cows * Labour	β_{52}				-0.0006
Health * concentrates	β_{53}				0.0001
Cows * health	β_{54}				-0.0044
Cows * produced fodder	β_{55}				0.0570
Inefficiency frontier model					
Intercept	δ_0	-4.94633**	-0.9067	-1.7096*	-0.4652
Age of household head	δ_1	0.00802*	-0.0576***	-0.0348.	-0.0291
Acres of fodder land	δ_2	-0.44717***	-0.4073***	-0.3249**	-0.2713.
Acres of grazing land	δ_3	-0.02519***	-0.0510***	-0.0572***	-0.0516*
Hourly wage rate	δ_4	0.20042	0.2463	0.3882	0.0530**
System (dummy:1 = Int., 0 = Ext.)	δ_5	0.99896*	-0.2764	-2.0451**	-1.5180*
Scale (dummy:1 = Sml., 0 = Med.)	δ_6	0.54996	0.1873	1.3588.	0.8707
Gender (dummy:1 = Male, 0 = Fem.)	δ_7	0.04999	0.8587	1.0500	0.9295
Hired labor (dummy:1 = Yes,0 = No)	δ_8	1.38063**	-1.5717***	0.1484	-0.2401
Access extn.(dummy:1 = Yes, 0 = No)	δ_9	1.41616***	0.6302	-0.1252	-0.4361
Paid extn.(dummy:1 = Yes, 0=No)	δ_{10}	0.48777	-0.8412	-0.7587	-0.4195
Paid water (dummy:1 = Yes, 0 = No)	δ_{11}	-0.06407	0.0700	0.7039	-0.4242
Hired land (dummy:1 = Yes, 0 = No)	δ_{12}	1.03041***	0.3016	0.8440.	0.7041
Age * Size fodder land	δ_{13}		-0.0394***	-0.0162.	-0.0104
Age * Size grazing land	δ_{14}		-0.0026***	-0.0025***	-0.0022***
Age * wage rates	δ_{15}		0.0472*	-0.0086	0.0089
System * Scale	δ_{16}		0.1928	0.5424	0.6655
Gender * hired labour	δ_{17}		0.0400	-0.1351	0.1376
Extension access * paid extension	δ_{18}		0.9995	-0.7587**	-0.4195
System * access to extension	δ_{19}		0.9634	2.2072	1.6131*
Scale * Gender	δ_{20}		-0.2463	-1.0247	-1.0294
Gender * access to extension	δ_{21}		-0.0536	-1.1522	-0.6770
System * gender	δ_{22}		-1.1091	1.0000**	1.0000
Hired labour * paid extension	δ_{23}		4.2317***	2.8884***	2.6968**
Model diagnostics					
Sigma-squared ($\sigma^2 = \sigma_v^2 + \sigma_u^2$)	σ^2	0. 8593***	0.2095***	0.3232***	0.1690***
Gamma ($\gamma = \sigma_u^2/(\sigma_v^2 + \sigma_u^2)$)	γ	0. 9099***	0.9455***	0.9610***	0.9382***
Total number of observations		85	85	85	85
Log likelihood value		-24.4045	11.9254	2.7593	3.9017
Mean efficiency		0.6768	0.6727	0.6796	0.7122

Source: EADD field survey (August 2012). Extn.= Extension

the output elasticity for each of the inputs calculated at the variable means. The principle underlying elasticity is the measure of responsiveness of an output to unit increase in input. From the Cobb-Douglas model the elasticity with respect to normalized unit cost of purchased fodder, conserved feeds and milk transport were significant (p-value <0.001). The elasticity with respect to water was significant at 5% (p-value <0.05). The negative coefficient signs of these variables imply that they are significant at reducing profits among smallholder dairy farmers. The absolute values of these coefficients suggest that a unit increase in the price of purchased fodder, conserved feeds, milk transport and purchased water have the ability to decrease efficiency by 5, 4, 3 and 4%, respectively. Despite the fact that the parameter coefficients for cost of breeding, health, extension, labour, concentrates, grazing and milk to calves were negative, implying that a unit increase in the price of these inputs decreases profit efficiency, their effects were found not to be significant (p-value >0.05).

The elasticity with respect to cost of farm produced fodder was significant (p-value <0.001) and with a positive coefficient. A unit increase in the cost of on-farm fodder led to 9% increase in profit efficiency. This indicates that investments in on-farm fodder production are a better feed choice in current dairy production in Kenya since it enhances profitability of the smallholder farmers. It was also observed that a unit increase in the number of cows of a household positively increased frontier function for milk gross margin, though not significant (p-value >0.05).

Determinants of profit efficiency among smallholder dairy farmers

This study considered several socio-economic characteristics that have the potential of influencing profit efficiency of the farmers (Table 4). The classical interpretation of inefficiency variables in the stochastic frontier function is based on the signs of the parameter estimates which are interpreted in the opposite manner to those of the general stochastic frontier model. A negative sign implies that there is an increase in profit efficiency associated with the inefficiency factor, while a positive sign means a decrease in efficiency. The socio-economic variables that significantly increased profit efficiency among the smallholder farmers were size of fodder land and size of grazing land. Efficiency increments associated with size of land for fodder and for grazing are in line with theoretical expectations. This is attributed to the lower unit feed costs in milk production of farmers with fair land sizes under fodder production and for grazing.

The study found that profit efficiency significantly decreased with age of the farm owner (p-value <0.05). This was mainly attributed to the high production costs associated with the elderly farmers especially due to hired labor services used on farm as a result of reduced mobility in farming, limited application of new technologies that are more efficient than the traditionally inefficient technologies, among others. The positive and the significant (p-value <0.05) impact of the production system variable indicated that farmers engaged in intensive system of dairy keeping tend to exhibit higher levels of inefficiency. This difference could arise due to the higher costs incurred in intensive systems, as well as inefficiencies in resource allocation that renders them less profitable as argued by Kumbhakar and Lovell (2000). Farmers' access to extension services was significant (p-value <0.0001) and decreased profit efficiency. In theory, the access to extension services paid for by the farmer can result into increased cost of milk production hence a decrease in milk gross margins. Hired labor and hired land were significant (p-value <0.01 and p-value <0.001, respectively) inefficiency factors at reducing profit efficiency among smallholder farmers. These findings tally with theoretical expectations, in that a farmer who relied entirely on household labor incurred no costs on labor and therefore their unit gross margins remained high and hence were more profit efficient. It is also true that paying for land for dairy activities increased the cost of milk production among farmers and hence caused such farmers to be less profit efficient. The study identified that factors such as gender, scale of production, wage rates, paid water and paid extension services were insignificant at influencing dairy profit efficiency among the smallholder farmers.

Efficiency distribution among dairy farmers

The mean profit efficiency of the smallholder dairy farmers approximated to 68% as earlier presented. It was also found that 54% of the farmers were distributed to a profit efficiency of greater than 70% (Table 5). The least farmer was 6.5% profit efficient, while the best farmer was 99% efficient. A general distribution of efficiency among other socio-economic characteristics is summarized in Table 6. Most of the observed differences are attributed to the costs incurred in production by the respective groups, and are in line with theoretical expectations.

CONCLUSION AND RECOMMENDATIONS

There has steadily been an increasing concern on feed resources for smallholder dairying in Kenya especially in the past decade. Stakeholders often cite high costs in milk production as farm technology is changing so fast to intensive systems. The study explored profit efficiency of smallholder dairy farmers in the Rift Valley and Central Provinces in Kenya. It was found that the farmers were 68% profit efficient. Despite this mean efficiency, there was a wide variation among the farmers, with 54% of them achieving a profit efficiency of more than 70%. The best farmer attained a maximum profit efficiency of 99%, while the least had 6.5%. Fodder produced on farm significantly improved profit efficiency among the dairy farmers. On the other hand, costs such as fodder purchased, conserved feeds, milk transport and water for cattle significantly reduced profit efficiency among the farmers.

The socio-economic variables that significantly influenced profit efficiency among the dairy farmers were size of fodder land, size of grazing land, age of farm owner, production system, extension service, hired labour and hired land. With an average profit efficiency of only 68%, the smallholders can further improve their profit efficiency if farmers' inefficient practices are improved. With the increasing competition for land resources, an average profit efficiency of only 68% among the farmers is an indication that the farmers are not very efficient in dairy production currently. Hence, efficient feed

Table 5. Profit efficiency indices of dairy farmers in Kenya**.**

Efficiency Class Index	Frequency	Percentage (%)	Cumulative Percentage
0.00 - 0.10	2	2.4	2.4
0.11 - 0.20	3	3.5	5.9
0.21 - 0.30	3	3.5	9.4
0.31 - 0.40	6	7.1	16.5
0.41 - 0.50	6	7.1	23.5
0.51 - 0.60	8	9.4	32.9
0.61 - 0.70	11	12.9	45.9
0.71 - 0.80	14	16.5	62.4
0.81 - 0.90	14	16.5	78.8
0.91 - 1.00	18	21.2	100.0
Total	85	100.0	

Source: EADD field survey (August 2012).

Table 6. Efficiency distribution among socio-economic groups.

Socio-economic characteristic	Dummy	Frequency	Efficiency
Gender	Female	29	0.67
	Male	56	0.68
Age below 51 years	No	26	0.64
	Yes	59	0.69
Extension services	No	24	0.71
	Yes	61	0.66
Paid extension services	No	75	0.67
	Yes	10	0.72
Employed labor	No	45	0.72
	Yes	40	0.63
Paid water services	No	77	0.67
	Yes	8	0.71
Paid land services	No	64	0.68
	Yes	21	0.66

Source: EADD field survey (August 2012).

technologies commensurate with farm local conditions are required. Institutional policy reforms targeting competitive dairy sector performance are needed so as to expand the productivity and profitability of the smallholder dairy farmers.

Conflict of Interest

The author(s) have not declared any conflict of interests

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