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# ASSESSING THE TECHNICAL EFFICIENCY OF SMALLHOLDER DAIRY FARMING IN KIAMBU COUNTY

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**ABSTRACT**

Kenya boasts one of the most impressive and advanced dairy industries in Sub-Saharan Africa that contributes about 12% to the national gross domestic product (GDP) and 42% to the agricultural GDP (Victor *et al.*, 2022). The industry is mainly dominated by small holder farmers, who make up 80% of the 1.8 million dairy farmers that are in Kenya (Okello *et al.*, 2021) most of whom come from the Central and Rift Valley provinces as these areas lie in suitable agro-ecological environments for dairy farming. Milk is primarily produced by smallholder dairy farmers under three main systems of production; open grazing, zero grazing and semi-zero grazing. Due to increasing urbanization, rising incomes and population growth, domestic and regional demand for milk is growing. This ever-increasing demand for dairy products presents smallholder farmers with a huge market opportunity. To meet this rising demand, it requires that farmers at the minimum undertake actions to boost their productivity and improve their efficiency. As a result, this study was undertaken to empirically estimate determinants of technical efficiency by applying Cobb-Douglass Stochastic frontier production (CD-SFP), and used a two-limit Tobit Model to evaluate the sources of inefficiencies. A cross-section survey was conducted to collect data on demographic and production factors from 398 small-holder dairy farmers in Kiambu County. The study achieved a 91.5% response rate, having received household surveys from 364 smallholder dairy farmers. The Estimations from the CD-SFP model showed that labour, feed, and herd size all had significant effects on milk yields. The estimates of coefficients of other explanatory variables of stochastic frontier production function (i.e. number of lactating cows, average daily cost of purchased supplements, average daily health/veterinary expenditure and average amount of water consumed daily) are found to influence amount of milk produced positively. The results showed that the average technical efficiency of farmers was 84.69%, with the majority of farmers achieving TE of 80% or higher and none achieving TE of 100%. The results revealed that technical efficiency was mostly influenced by years of learning and access to extension services. Despite the inefficiencies, the findings showed that there is still potential for small-scale dairy farmers in Kiambu to increase their productivity by utilizing current technology and resources. The increasing return to scale revealed that farmers use resources reasonably efficiently and that milk production may improve if inputs were increased. The study suggests promoting strategies to increase the availability of informal education among dairy farmers, which can be leveraged to make extension services more effective. This will help improve the adoption of new technologies in the sector. Efforts should be made to enhance the bureaucratic milieu for the provision of extension services as this can enhance milk yields and productivity.

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

## 1. INTRODUCTION

Food insecurity and low agricultural productivity are the two main issues that farmers in East Africa remain determined to address. Given that the agricultural sector provides employment to about 75%, 80% & 66% of the population in Kenya, Tanzania and Uganda respectively, it is imperative that farmers find solutions to low agricultural production, which is the main source of poverty among many rural residents (FAO, IFAD, & WFP., 2015). Dairy farming, for instance, is the largest single subsector of agriculture in Kenya. It contributes around 12% of the country's GDP (Victor *et al.*, 2022). The industry directly contributes to the livelihood of approximately 1 million small scale farmers. According to IFAD (2006), 54% of the households in Kenya with 1 acre or less rear cattle. Dairy farming can be described as the keeping of cattle, goats, sheep, and camels for purposes of milk production.

A smallholder dairy farmer is described as a farmer who operates on small farms often comprising less than 5 hectares of land, and keeps between 1 to 5 dairy cows that are usually of improved (McDermott *et al.*, 2010). Smallholder dairy farmers depend on dairy products for subsistence and commercial purposes. Of the entire herd of dairy cattle kept in Kenya, smallholder farmers own 80% of them. The main breeds that are kept for dairy production include the Friesian, Ayrshire, Jersey, Guernsey, and their crosses (Kibiego *et al.*, 2015). Approximately 80 % of the milk produced in the country is produced and marketed by smallholder dairy farmers (Bateki, *et al.*, 2020). As a result, the sector is essential in improving farmers' livelihoods and reducing poverty in the country. However, there are several factors that limit farmers from fully enjoying their returns; these mainly include high costs of production and low productivity, among others. Productivity can be defined as the measure of efficiency of a farmer to convert inputs into outputs, which in this case is the milk yield per cow. Dairy farming is not only one of the most profitable enterprises, but also significantly contributes to food security all over the world. The global average for milk production stands at 2200 litres per cow per year (FAO, 2019). Some of the highest milk producing regions in the globe such as the Netherlands, USA and Israel average between 8000-10000 litres of milk per cow per year (McCullough, 2019). Meanwhile, in Kenya, farmers are only averaging 1800 litres of milk per cow per year, a figure that still lies below the global average (FAO, 2019). This means that the farmers in Kenya are not able to enjoy the good returns that dairy farming has to offer due to low production.

Several factors limit smallholder dairy farmers from achieving maximum gains from their dairy cows. These factors are closely interlinked with land size and high human population. Consequently, dairy farmers opt to keep their cattle under intensive and semi-intensive production systems. The system of production employed in a particular area is dependent on the population density as well as the agro-ecological zone of that area (Staal *et al.*, 2003). In Kenya, there are three distinct systems of production employed in the dairy sector; the intensive system of production also known as zero grazing, semi-intensive system of production (semi-zero grazing), and free ranging system of production (traditional grazing).

In the Kenyan highlands, where the population density is high and individual land size is gradually reducing with time, the main system of production used by the smallholder farmers is the intensive production system, which involves stall feeding the cows with planted fodder crops and supplementing them with concentrates. However, in moderately populated areas, the main system of production employed is the semi-intensive, where farmers either feed their animals in stalls or graze them depending on the season. According to Bebe et al. (2003) 44% of the households in the Kenya highlands practise intensive dairy farming, 33% practise zero grazing and 23% practise semi-zero grazing.

### 1.1 Statement of the problem and objectives

According to (Kokkinou and Geo, 2009), Technical Efficiency estimation gives an indication of the percentage by which a farmer could increase the potential output with respect to the corresponding production frontier. An ideal farm under the perfect conditions, would exhibit a technical efficiency score of 1, meaning this farm is 100% technically efficient. However, producers are hardly ever fully productively efficient. The difference can be brought about by allocative and technical inefficiencies, as well as a range of unforeseen exogenous shocks (Rei Schneider and Stevenson, 1991). European farms, nonetheless, are some of the most productively efficient farms, with the average technical efficiency in the EU standing at 0.9 (Náglová, and Rudinskaya, 2021).

In Kenya, however, there are several factors that limit the Kenyan dairy farmer from operating at the high-level frontier of milk production that highly efficient producers such as those in the EU operate. Some of these factors include low quality feeds, poor animal husbandry practices, competition for resources and other environmental factors (McCullough, 2019). For the small-scale farmers, the majority of these factors could be viewed as sources of inefficiency. Moreover, farmers are facing unique challenges due to the varied agro-ecological conditions. Farmers' productivity in the dairy business has been hampered as a result of these circumstances, and farmers are faced with difficult decisions about the best practices to apply in order to generate reasonable returns. For instance, increased human population especially in the highlands where Kiambu lies and dairy farming thrives has led to great land fragmentation. This fragmentation limits the cultivation of fodder; thus, farmers end up underfeeding their cows (Ichaura, 2013). As high potential agricultural land diminishes, it is essential that farmers attain high levels of efficiency to contribute to household food security and overall national development. Therefore, the rapidly declining household land sizes, is a pre-requisite for increased dairy production intensification to achieve the maximum benefit for the farmers. For the farmers to achieve maximum benefits, there is need for them to be technically efficient so that they can get good returns from their herd. The objective of this study was therefore to assess the level of technical efficiency of smallholder dairy farmers in Kiambu County as well as determine the demographic and socio-economic characteristics that have an influence on TE.

### 1.2 Significance of the study

Dairy farming is crucial for Kenya's economic activities as it provides employment opportunities and contributes to the country's food security and national GDP. Milk from livestock is estimated at 5.2 billion litters annually, the bulk of it (75%) coming from cows and most of it being produced by smallholder farmers. An increasing demand from milk due to growing human population, increasing urbanization and rising incomes has been noted. To meet this demand, productivity needs to grow. A study conducted by USAID (2014) projected that Kenya would experience a milk deficit of 1.2 billion litters by the year 2022 in the absence of significant improvements in milk yields. A similar study concluded that for the country to meet the projected demand at current productivity levels, increasing domestic production would require farmers to more than double their existing herd size in the next decade (USAID, 2018) a scenario that is not practical given the constraints in land, water and other resources. The increasing demand for dairy products presents small-scale dairy producers with a huge market opportunity. Nevertheless, this requires, at the minimum, that the smallholder farmers, who dominate the industry, to increase productivity and improve their efficiency. Productivity in dairy farming is integral in ensuring continuity and longevity, and if streamlined properly, it can provide sufficient and steady incomes to farmers, their families, and all stakeholders involved. Therefore, this study would be helpful to farmers, as it would inform them of the factors that influence technical efficiency, which, in turn, affects productivity in dairy farming. The government could use the information from this research to come up with policies on the dairy sector, or better yet, when providing extension services to farmers to fully inform them of their alternatives and how they could increase technical efficiency and maximise dairy productivity. Other researchers may also use the findings as reference material in the future.

## 2. MATERIALS AND METHODS

### 2.1 Study area

The study was carried out in Kiambu county, an area located in central Kenya, 22 kilometres from the capital city. The region is situated in Agro-ecological zone II, and receives an annual rainfall of 989mm. The temperatures range anywhere from 12 degrees centigrade during the cold season to about 24 degrees centigrade with an average of 18 degrees centigrade (Kiambu government, 2016). Farming and agriculture are the main economic activities practised in this area that is predominantly occupied by the Kikuyu, a majority tribe in Kenya. The total area covering Kiambu County is approximately 2543 square Kilometres with a population of 1,623,282 citizens. Its population density is at 638 people per square Kilometre with an annual growth rate of 2.56% (Kiambu government, 2016). Its arable land, ideal temperatures, rich highland soils and adequate rainfall makes agriculture, together with other activities such as manufacturing and food processing, play a major role in the economic development of the area.

#### 2.1.1 Sampling technique and collection method

A multistage sampling technique was used for this study whereby Kiambu county was conveniently selected, six out of the twelve sub counties purposefully selected and the farmers randomly and systematically selected from their cooperatives. A descriptive household survey using structured questionnaires was used to collect primary data from the respondents. The total number of households that were sampled were 398. Out of this, 368 responded, which signifies a 91.5% response rate.

### 2.2 Empirical model specification

The study used a two-stage estimating technique to first estimate efficiencies obtained from the Cobb Douglass SPF, and then, using a two-limit Tobit regression, the TE scores were regressed against regressors established as the sources of inefficiencies, which are demographic characteristics. The Cobb-Douglas function-based SFP model was estimated to achieve research objective one of assessing individual farmer level technical efficiency. Furthermore, the methodology helped the determination of the connection between the dependent variable (TE) and the independent variables (factors that affect TE).

$$TE = f(F, S, I) \quad (1)$$

Where F represents factors of production; S denotes socioeconomic factors, I denote institutional factors, and TE denotes technical efficiency of farmer.

#### 2.3.1 Stochastic Production Frontier Functions

The technical efficiency of a farm can be defined as the ratio of the observed output vis-à-vis the frontier output while considering the available technology (Al-Sharafat, 2013). A Stochastic Production Frontier (SPF) framework was used in the research to estimate the technical efficiency of individual farms. The SPF is expressed as follows:

$$Y_i = f\left(X_{ij}B\right)\exp\left(V_i - U_j\right), i = 1,2, \dots \dots \dots \dots . nth\ farmer, \quad (2)$$

Where $Y_i$ is the ith farm output, rather milk production in litres per year; $X_i$ , is the vector of input quantities used by the ith farm, $\beta$ is vector of parameters to be estimated, $f$ represents the appropriate function, which is Cobb Douglas production function in our case. $V_i$ represents random variation in output that occurs due to factors that are beyond the farmer's control, and $U_i$ represents a non-negative random variable that accounts for statistical noise.

The Cobb-Douglass SPF function is estimated as follows:

$$lnY_i = \beta_0 + \beta_1 lnLand + \beta_2 lnLab + \beta_3 lnherd + \beta_4 lnFeed + \varepsilon_i, \quad i = 1, 2, 3, \dots\dots 398 \qquad (3)$$

In represented natural logarithm; $\beta_0$ is an intercept parameter to be estimated; $(\beta_1, \beta_2, \beta_3, and\ \beta_4)$ are parameters of the input to be estimated; $\varepsilon_i$ denotes a composite error term $\{(V_i - U_i)\}$, where $V_i$ is random error that is *iid* and $U_i$ is the stochastic efficiency component that signifies deviations from the frontier associated with inefficiency. It is deemed to be *iid* $(u \sim N[0, \sigma_u^2\ ])$. Given the stochastic production frontier equation, the level of technical efficiency (TEi) of each dairy smallholder farm is as follows:

$$TE_i = Y_i / Y_i^* = \frac{f(x_i, \beta)\exp(V_i - U_i)}{f(x_i, \beta)\exp(V_i)} = \exp(-U_i) \qquad (4)$$

Where $Y_i$ =observed output and $Y_i^*$= frontier output. Since $U_i$ is a nonnegative and truncated normally distributed random variable, $TE_i$ ranges from 0 to one. Technical efficiency is defined as the existence of solely individual discrepancies when a farmer's actual output value $Y_i$ is smaller than the maximal production scale $f(x_i, \beta)\exp(V_i)$.

### 2.3.2 Tobit regression

A two-limit Tobit regression model was used to determine the sources of inefficiencies. Tobit model, which is built around the principle of maximum likelihood (Maddala, 1999), is technically favoured over OLS, because the TE scores from CD-SFP are censored at both limits of 0 and 1. According to Cameron and Trivedi (2009), estimating OLS in the context of censoring result in computational constraints. That is, OLS regression will not generate consistent parameter estimates since the censored sample is not reflective of the population. Theoretically, the two-limit Tobit model is expressed as:

$$TE_i = \delta_0 + \delta_1 Z_{i1} + \delta_2 Z_{i2} + \delta_3 Z_{i3} + \delta_4 Z_{i4} + \delta_5 Z_{i5} + \delta_6 Z_{i6} + \delta_6 Z_{i6} + \epsilon_i \qquad (5)$$

Whereas $i$ denotes the ith *dairy* farmer sampled $TE_i$ is the ith TE score 7 $Z_s$ denotes to the institutional and social economic variables associated with the dairy farmer $\delta_i s$ are parameters to be estimated; and $\epsilon_i$ is a stochastic error that is presumed normally distributed. For the sources of inefficiencies, the Tobit Model incorporated the following variables:

$Z_1$ Representing the Age of the $i^{th}$ household head
$Z_2$ Representing the Level of Education of the $i^{th}$ household head
$Z_3$ Representing the Dairy Farming Experience of the $i^{th}$ household head
$Z_4$ Representing the Gender of the $i^{th}$ household
$Z_5$ Representing the Other Sources of Income of the $i^{th}$ household head
$Z_6$ Representing Access to Credit by the $i^{th}$ household head
$Z_7$ Representing Access to Extension services by the $i^{th}$ household head

## 3. RESULTS AND DISCUSSION

### *3.1 Summary Statistics*

The summary statistics for the variables used in the stochastic production frontier model are presented in Table 1. The average farm size was 1.87 acres, with a standard deviation of 1.46, indicating that the majority of dairy producers operate on a small scale. The farms ranged in size from 0.12 to 10 acres. The limited land size forces farmers to maximize farmland intensively to satisfy food demand while allocating barely any area towards fodder cultivation, (Kilungo et al., 1999).

**Table 1: Summary statistics for the stochastic production model variables**

| Variable | Unit | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Annual yield per household | Litres | 4553.07 | 2671.05 | 3050 | 29585 |
| Daily Milk yield per household | Litres | 14.92 | 8.76 | 10 | 97 |
| Total Man-days | Number | 226.16 | 55.14 | 76 | 382 |
| Land (Farm size) | Acre | 1.87 | 1.46 | 0.12 | 10 |

| | | | | | |
|---|---|---|---|---|---|
| Herd size (of lactating cows) | Number | 2.69 | 1.26 | 1 | 5 |
| Daily Fodder (Feed) per cow | Kgs | 37.74 | 7.48 | 7.48 | 77.97 |

**Source: Field survey (2022)**

The mean herd size was 3 cows with a standard deviation of 1. Smallholder farmers are associated with small herd of animals that range between one and five (Odero-Waitituh, 2017). The variables utilized for stochastic frontier production were Annual milk production, herd size of lactating cows; feed (kg/herd), Labour (man-days), and land size (acres). The average daily milk yield was determined to be 14.92 liters with a big range having the daily minimum yield 10 liters and the Maximum yield 19.4 liters. This was achieved by dividing the minimum daily milk yield per household by the number of cows in that household (1) and dividing the maximum daily milk yield per household by the number of cows in that household (5). The study by Maina et al., (2018) also obtained monthly milk production with wide ranges. The average herd size for lactating cows was roughly three cows, with one cow being the smallest and 5 cows being the largest herd. This research finding supports the findings of Odero-Waitituh (2017), who reported that small-scale dairy farmers own between 1 and 5 cows per herd on average. The daily amount of fodder provided to each cow averaged 37.74 kgs, which validates Mugambi's (2014) study, which indicated that the average daily fodder given to the cow was 52.12 kgs. The mean total labor man-days for each dairy farm were determined to be 226.52. However, the majority of the labor was provided from family members. Moreover, this labor input has received insufficient attention and credit, creating concerns about gender disparities in farm labor allocation.

**3.2 Maximum likelihood Estimation of the Stochastic Production frontier**

The output of the maximum likelihood (ML) parameters of the stochastic frontier production (SFP) that were predetermined to assess the variables impacting dairy farming in Kiambu County is presented in table 2. The variance parameter gamma (0.984) was significantly different from zero, indicating the existence of inefficiencies among the smallholder dairy farmers. As a result, the parameter showed that 98.4% of the deviations in the composite error terms were explained by inefficiencies, making the SPF the most appropriate model for this study.

Additionally, the existence of technical inefficiency is examined by employing the Likelihood Ratio Test suggested by Kumbhakar, et al., (2015), which is computed as $-2(L[H_0] - L[H_1])$: where, $(LH_0)$ is loglikelihood metric derived from generalized linear model (GLM) (appendix 1), while $(LH_1)$ is derived from unrestricted SFM. Given that the value from the restricted LR is -12.15, while the value from the unrestricted LR is -4.447, the value that ensued upon computing the LR-Test $(-2(L[H_0] - L[H_1])$ is 15.406. The mixed distribution of Kodde and Palm (1986) yielded a critical value of 8.761 at 5% significance level (annex). Since 8.761 is less than 15.406, we may disregard the null hypothesis of no technical inefficiencies in our model, implying that the Stochastic Production Frontier is appropriately specified for this investigation. Furthermore, the estimated value of sigma squared $(\sigma_s^2 = \sigma_u^2 + \sigma_v^2)$ is 2.1226 at $(p < 0.01)$ and the log likelihood statistic -4.4470 $(p < 0.01)$ demonstrates the model's appropriateness.

The findings indicate that three of the four variables introduced into the SPF model were important predictors of milk output in dairy farming. The three variables included; LNLabour, natural log of labour in man-days, LNHerds, natural log of herd size (representing lactating herd size), and LNFEEDS, natural log of fodder in kgs provided to the cows. SPF variable estimates and annual milk output were projected to be positively correlated. This indicated that increasing the number of man-days, herd size, and feed would almost certainly increase milk output. The Herd size elasticity was significant at 1% and had highest elasticity of output to Feed at 0.65, suggesting milk yields is greatly sensitive to the number of cattle one has. This can be validated by findings from Cabrera et al. (2009), which showed that the variable with the greatest impact on production was the number of cows on the farm. Consequently, a 1% increase in the number of Herds resulted in a 0.65% increase in milk output, all else being equal. The land size was found negligibly significant, but at 1% alpha levels, the coefficients of the labour and the quantity of feed were both positive and significant, implying that a 1% increase in labour input and quantity of feed would result in high milk yields by 0.5% and 0.37%, respectively. The favourable influence of herd size on milk output is consistent with the findings of Mugambi (2014) and Cabrera et al (2009). In terms of feed, Richards et al. (2016) discovered that adding 1kg of dairy meal concentrate per day resulted in an increase of 0.53kg of milk per cow per day.

**Table 2: Maximum likelihood estimates of the stochastic frontier production function**

| LYIELD | Coefficients | Robust std-errors | Z | P>\|Z\| |
|---|---|---|---|---|
| LNLabour, Man-days | 0.504959 | .0609331 | 8.29 | 0.000 |
| LNLand | 0.23392 | 0.158947 | 1.47 | 0.141 |
| LNHerds | 0.6453251 | .0712342 | 9.06 | 0.000 |
| LNFEEDs | 0.3711486 | .0569847 | 6.51 | 0.000 |
| Const. | 2.062563 | .6237874 | 3.31 | 0.001 |
| **Diagnostic statistics** | | | | |
| Wald Chi2(4) | 2993.03 | | | |
| Prob>Chi2 | 0.0000 | | | |

| | |
|---|---|
| Log likelihood | -4.4470 |
| Sigma square ($\sigma_s^2 = \sigma_u^2 + \sigma_v^2$) | 2.1226*** |
| Gamma $\gamma = (\sigma_u^2/\sigma_s^2)$ | 0.984 |
| Lambda (λ)= ($\sigma_u^2/\sigma_v^2$) | 9.9555*** |

**Table 3: Summary statistics of technical efficiency scores**

| Efficiency Score (%) | TE (frequencies) |
|---|---|
| **91<%score<100** | 121 |
| **81-90** | 176 |
| **71-80** | 36 |
| **61-70** | 20 |
| **51-60** | 7 |
| **41-50** | 4 |
| **<40** | 0 |
| **Mean (%)** | .84.69% |
| **Std Deviation** | 9.33% |
| **Minimum (%)** | 42.81% |
| **Maximum (%)** | 96% |

### 3.3 Distribution of Technical efficiencies among small scale dairy farmers in Kiambu

The percent values indicate that the majority of farmers are technically inefficient, implying that their levels of performance were less than 100% and that they were operating below the frontiers. For example, the wide range of technical inefficiency reveals that the majority of farmers are employing their inputs inefficiently. Kimenchu et al., (2014) corroborated similar findings. The mean efficiency levels (84.69%) suggest that waste accounts for only a minor portion of output (15.31 percent). However, with a maximum efficiency of 96%, the dairy farmer will save 4% (100%-96%) off their expenses if they run on the frontier. Conversely, the least efficient dairy farmer keeps back 59.57% $[1-\{(57.19\%)/(96\%)\}]$ in general terms. Overall, none of the dairy farmers achieved 100% technical efficiency, indicating that there is significant scope for growth in Kiambu dairy farming given the current technology and resources.

### 3.4 Determination of socioeconomic factors affecting technical efficiencies

The study further evaluated the sources of technical inefficiencies using a two-limit Tobit model, which assisted in estimating the sources of inefficiencies between the technical efficiency scores and the vector of social economic factors. Table 4 reports the Tobit findings in which seven variables investigated accounted for a significant proportion of the variation in technical efficiencies. These include; gender of the household head, age of the farmer, years of education, farming experience, access to extension services, access to credit, and income sources. According to table 4, years of schooling and access to extension coefficients were found to be statistically significant in determining efficiency levels.

Education was determined to be positive and significant at 1% significance suggesting that each 1% rise in years of education translates in an approximately 1.7% gain in TE. Undoubtedly, the higher educated farmer is likely to perform more effectively and employ more sophisticated production methods compared to the less trained farmer. Girma's (2019) study supports the notion that increased years of education lead to a reduction in technical inefficiencies among smallholder dairy farmers. Education enhances the knowledge and entrepreneurial abilities of farmers, enabling them to effectively allocate resources for optimal efficiency, including enhancing milk production by accessing and utilising dairy technologies. Additionally, their educational attainment plays a crucial role in the effective utilisation of these technologies (Wilkes et al., 2018; Okello et al., 2021). Education enhances awareness and facilitates shifts in mindsets, thereby fostering an enabling atmosphere for technology adoption (Mwanga et al., 2019).

**Table 4: Tobit model results on the sources of technical inefficiency**

| Technical Efficiency | Coefficient | Std. err. | t | P>t |
|---|---|---|---|---|
| **Gender of Household Head H** | -.00418 | .0132465 | -0.32 | 0.753 |
| **AGE** | -.0004536 | .0006477 | -0.70 | 0.484 |
| **Years of Education** | .0166937 | .0071319 | 2.34 | 0.020 |
| **Income sources** | .0021551 | .0085776 | 0.25 | 0.802 |
| **Experience** | .043358 | .0007213 | -0.39 | 0.695 |
| **Access to extension** | 0.043358 | .0153452 | 2.83 | 0.005 |
| **Access to credit** | .0007985 | .013712 | 0.06 | 0.954 |
| **_cons** | .8079583 | .0373418 | 21.64 | 0.000 |

**Source: Author's computations**

Access to extensions services exhibits a positive and statistically significant influence on technical efficiency, as evidenced by the 1% significance level. This implies that for every 1% rise in the utilisation of extension services, there is a corresponding

4.3% increase in technical efficiency. Historically, public extension workers have been responsible for delivering veterinary services to smallholder farmers. Privatisation has been implemented in response to the declining supply of extension workers, resulting in the public sector assuming an oversight function over the provision of agribusiness assistive service (K'Oloo & Ilatsia, 2015). Farmers typically operate within cooperatives that offer them private extension services. These services are primarily commercially focused and aim to retain clients by rendering top-notch assistance. Consequently, farmers are likely to increase their investment in private service providers to enhance their capacity to improve milk yields and productivity.

## 4. CONCLUSION AND RECOMMENDATIONS

The smallholder dairy farmers underfeed their cows, giving them around 38 kilos of fodder (feed) against the recommended 100 kgs. This could be attributed to increasing land fragmentation, which leaves farmers with little room to plant fodder for their herd as well as the high costs of feeds, making purchased feed unaffordable. The study findings revealed that most dairy farmers operated at an average technical efficiency of 84.69% with the majority of farmers performing above 80%, while no dairy farmer attained 100% technical efficiency. These findings indicate the available potential for small-scale dairy farmers in the study area to increase productivity by utilizing current technology and resources. Furthermore, the study found that increasing herd size, feed and labour resulted in increased milk output; however, educational levels and access to extension services are responsible for technical efficiencies. The increasing return to scale revealed that farmers use resources reasonably efficiently and that milk production may improve if inputs were increased. In regard to the underlying sources of inefficiency, the study concluded that level of education, and access to extension services significantly impacted technical efficiency positively. It is recommended that Dairy farmers should get both informal and formal education to increase their competence and productivity potential, as well as the adoption of novel and current milk production practices. Further, the imperative task necessitates a thorough and meticulous re-evaluation of the extension programme, ensuring its alignment with the specific needs and aspirations of the dairy farmers. Only through such a comprehensive redesign can the programme effectively fulfil its intended purpose, namely the enhancement of the farmers' technical proficiency.

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## REFERENCES

Al-Sharafat, A. (2013). Technical Efficiency of Dairy Farms: A Stochastic Frontier Application on Dairy Farms in Jordan. *Journal of Agricultural Science, 5*(3). doi: 10.5539/jas.v5n3p45

Bateki, C., van Dijk, S., Wilkes, A., Dickhoefer, U., & White, R. (2020). Meta-analysis of the effects of on-farm management strategies on milk yields of dairy cattle on smallholder farms in the Tropics. animal, 14(12), 2619-2627.

Bebe B.O, Udo H M J, Rowlands G. J and Thorpe W (2003). Smallholder dairy systems in the Kenya highlands: cattle population dynamics under increasing intensification. Livestock Production Science, 82: 211-22.

Cabrera, V. E., Solis, D., & del Corral J. (2009). Determinants of technical efficiency among dairy farms in Wisconsin. J. Dairy Sci. 93, 387–393

FAO.ORG. (2019). *FAO Statistical Yearbook 2012*. [online] Available at: http://www.fao.org/3/i2490e/i2490e00.htm

FAO, IFAD, & WFP. (2015). The State of Food Insecurity in the World 2015. Meeting the 2015 international hunger targets: taking stock of uneven progress. Rome, FAO.

Girma, H., (2019). Estimation of technical efficiency of dairy farms in central zone of Tigray National Regional State, Heliyon, Volume 5, Issue 3, e01322, https://doi.org/10.1016/j.heliyon.2019.e01322.

Ichaura, J. W. (2013). Constraints inhibiting profitability of small holder dairy farmers in Nyeri South Sub County, Kenya (Doctoral dissertation). http://repository.dkut.ac.ke:8080/xmlui/handle/123456789/132. Last accessed May 10, 2018

IFAD (International Fund for Agricultural Development) 2006 Small Holder Dairy Commercialization Programme- Appraisal Report: Africa Division 11, Programme management Department. Rome, Italy.

Kiambu.go.ke. (2016). [online] Available at: http://www.kiambu.go.ke/images/docs/other/PROJECTS-PROGRESS-REPORT-FOR-ROUTINE-MAINTENANCE.pdf [Accessed 29 Nov. 2019].

Kibiego. M. B, Lagat. J. K and Bebe. B. O. (2015) Competitiveness of Smallholder Milk Production Systems in Uasin Gishu of Kenya. Journal of Economics and Sustainable Development, 6 (10): 39-45.

Kilungo JK (1999). An Economic Analysis of Smallholder Dairy Production in Kiambu District, Kenya. A PhD. Dissertation. University of Nairobi

Kimenchu, Mugambi & Mwangi, Maina & Wambugu, Stephen & Macharia, Gitunu. (2014). Evaluation of Technical Efficiency of Dairy Farms in Eastern Central Highlands, Kenya. 3. International Journal of Innovative Research and Development.

Kokkinou, A., & Geo. (2009). Stochastic frontier analysis: Empirical evidence on Greek productivity. Glasgow. University of Glasgow.

K'Oloo T.O. & Ilatsia E.D. (2015). Who offers veterinary services to smallholder dairy farmers in western Kenya? Lessons from kakamega county, E.A. Agric. & Forestry J. 81 (1) 46–50, https://doi.org/10.1080/00128325.2015.1041253.

Kumbhakar, Subal & Horncastle, Alan & Wang, Hung-Jen. (2015). A Practitioner's Guide to Stochastic Frontier Analysis Using STATA. 10.1017/CBO9781139342070.

Maina, F., Mburu, J., Gitau, G., VanLeeuwen, J., & Negusse, Y. (2018). Economic efficiency of milk production among small-scale dairy farmers in Mukurweini, Nyeri County, Kenya.

McCullough, C. (2019). *Israel opens market: Farmers are worried*. [online] Dairy Global. Available at: https://www.dairyglobal.net/Market-trends/Articles/2019/1/Israel-opens-market-Farmers-are-worried-378685E/

McDermott, J. J., Staal, S. J., Freeman, H., Herrero, M., & Van de Steeg, J. (2010). Sustaining intensification of smallholder livestock systems in the tropics. Livestock science, 130(1-3), 95- 443 109.

Mugambi, D. K. (2014, May). Estimation of milk production efficiency of dairy cow farms in Embu and Meru counties of Kenya. In Scientific Conference Proceedings.

Mwanga G., Mujibi F.D.N., Yonah Z.O., Chagunda M.G.G., (2019). Multi-country investigation of factors influencing breeding decisions by smallholder dairy farmers in sub-Saharan Africa, Trop. Anim. Health Prod. 51 (2) 395–409, https://doi.org/10.1007/s11250-018-1703-7.

Náglová, Z. and Rudinskaya, T. (2021) 'Factors influencing technical efficiency in the EU dairy farms', *Agriculture*, 11(11), p. 1114. doi:10.3390/agriculture11111114.

Odero-Waitituh J A (2017): Smallholder dairy production in Kenya; a review. Livestock Research for Rural Development. Volume 29, Article #139. Retrieved April 29, 2023, from http://www.lrrd.org/lrrd29/7/atiw29139.html

Okello, D. *et al.* (2021) 'Determinants of utilization of agricultural technologies among Smallholder Dairy Farmers in Kenya', *Journal of Agriculture and Food Research*, 6, p. 100213. doi:10.1016/j.jafr.2021.100213.

Reifschneider, D. and Stevenson, R. (1991). Systematic Departures from the frontier: A Framework for the Analysis of Firm Inefficiency. International Economic Review 32(3), 715-723.

Richards S, VanLeeuwen J, Shepelo G, Gitau GK, Kamunde C, Uehlinger F and Wichtel J (2015). Associations of farm management practices with annual milk sales on smallholder dairy farms in Kenya. Veterinary World 8, 88–96.

Staal S. J, Waithaka M, Njoroge L, Mwangi D. M, Njubi D and Wokabi A (2003). Costs of milk production in Kenya. SDP Research and Development Report 1.

USAID-KAVES 2018. USAID KAVES Dairy Value-Chain Analysis

Victor, M., Rao, J. and Baltenweck, I. (2022) 'The Kenyan dairy and poultry sectors to benefit from a new research initiative', *International Livestock Research Institute* [Preprint].

Wilkes A., Odhong C., Ndonga S., Sing'ora B., Kenyanito L. 2018. Access to and Supply of Finance for Enhancing Dairy Productivity. CCAFS Working Paper No. 232. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Available online at:www.ccafs. cgiar.org.