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Profit Efficiency and its Determinants among Traditional Beef Cattle Farmers in the Meatu District of Simiyu Region, Tanzania

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Authors' contributions

This work was carried out in collaboration among all authors. Author CAK Managed data curation, formal analysis, investigation, methodology, validation, writing-original draft, and writing review & editing. Author LK Managed investigation, funding acquisition, supervision, and writing review & editing. While author YZ managed conceptualization, project administration, provision of resources, Software, Supervision, and visualization. All authors read and approved the final manuscript.

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ABSTRACT

Tanzania has taken great steps to commercialize the beef cattle industry since 1997. However, despite efforts, 22% of farmers live in poverty, and industry's contribution to GDP is low. This raises questions concerning beef cattle farmers' profit efficiency (PE). This study, thus, sought to gain empirical evidence on the level of profit efficiency (PE) and its determinants among farmers to

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discover ways to optimize the industry's commercialization to reduce poverty. This study uses field survey data from 393 farmers in the Meatu District of the Simiyu Region. Data were analyzed using descriptive statistics, Cobb-Douglas stochastic frontier profit function (CDSFPF), and Heckman treatment effect (HTE) models. The descriptive results showed that farmers had low levels of education, limited access to credit and veterinary services, and limited involvement in farmer cooperatives. Such limitations tend to lower profit maximization. Profit efficiency (PE) results showed that farmers lose 51% of their profits, with an average PE of 49%. Based on the maximum likelihood estimation (MLE) of CDSFPF, the cost of medications, supplements, labor, parasite eradication, marketing, transportation, and local breed beef cattle had a significant negative impact on PE at a 5% ($P < 0.05$) level. While grazing land owned and cattle herd size positively influenced PE at a 5% ($P < 0.05$) significant level. Thus, controlling variable costs to the utmost will increase PE and provide a substantial benefit. Besides, the estimated CDSFPF, along with the inefficiency variables and robustness test, show that access to market information, credit, educational level, farming experience, off-farm income, and cattle fattening all have a negative influence on profit inefficiency at the 5% ($P < 0.05$) significant level, thereby enhancing PE. Whilst the distance to the market increased the level of profit inefficiency, thereby decreasing PE. Therefore, the government should address factors that influence cattle production efficiency to boost farmers' income, the economy, and food security and reduce poverty.

Keywords: Beef cattle farming; profit efficiency; commercialization; poverty reduction; Tanzania.

1. INTRODUCTION

Global increases in beef meat demand and consumption are determined to hold beef cattle farming as one of agriculture's quickest industries of the economy for the forthcoming years, especially in medium- or low-income and poorer nations [1]. Notably, beef meat is an important commercial product with a relatively high level of sales among several types of meat [2]. As a result, beef cattle farmers are now in an excellent position to enhance their living standards by efficiently participating in the rapidly expanding beef cattle industry [1]. Similarly, substantial evidence suggests that maintained rises in beef meat consumption broaden dozens of new major investment potentials for traditional beef cattle farmers, who had historically been disconnected from economic expansion [3]. This implies that it is critical to improve efficiency and supplies, for example, by optimizing resource usage at the farmers' fields. Given the apparent issue of resource constraints, it is valuable to improve traditional beef cattle farmers' capability of producing extra, or at least the present rate of the outcome, at the cheapest cost to maximize profit efficiency (PE) [4].

In Tanzania, beef cattle production is, to a great extent, traditional [5, 6, 7]. Around 94% are primarily raised using the traditional method, which involves free-range production. In contrast, a smaller proportion of approximately 6% is attributed to commercial beef cattle farming [8, 9]. The country is estimated to have a beef cattle population of over 34.5 million with a 2.8% annual growth rate [1, 6, 7, 10, 11]. The traditional beef cattle farming industry comprises 98% indigenous beef cattle, which have been not succeeding in productivity but have great potential if nutrition, healthcare, and genetic improvements are realized [9, 11]. The industry is primarily hampered by poor farming techniques, a lack of modernization, stock acquisition far above adaptive capacity, and poor market- orientation. Besides that, prolonged shared public grazing is exercised on outdoor public pastures in the traditional beef cattle farming industry, which mostly neglects grazing land monitoring and inventory control using an adaptive approach. This usually leads to overcapacity, which degrades grass and land. Despite all the challenges, this industry has supported traditional beef cattle farmers' livelihoods for several centuries [12, 13]. Thus, the traditional beef cattle farming industry needs a comprehensive beef cattle policy to aid all key players in terms of developing and achieving its objectives (commercialization), particularly profit efficiency maximization.

The beef cattle farming industry in Tanzania plays a crucial role in the country's economic growth. According to the MLFD [10] and URT [6], the beef cattle industry contributes to around 50% of the money generated by farmers, 5.9% of the Gross Domestic Product (GDP), as well as export earnings and employment opportunities. According to the National Bureau of Statistics (NBS) [14], almost one-third of the nation's households are employed in the industry in question. The economic potential of traditional beef cattle farming industry has remained mainly unexploited due to limited commercialization [15, 16].

According to Sidhu et al. [17], the concept of input utilization pertains to the allocation of resources, including land, labor, capital, and management, in their various manifestations. The concept entails optimizing the utilization of a specific resource supply to achieve the highest possible outcome (profit), whether it is in terms of financial profit, caloric value of food, or national income. According to Effiong [18], there is a crucial need to ascertain the understanding of the connection between resources and products, as it serves as a valuable tool in identifying issues related to production and resource utilization. Once these resources are prudently employed, farm-level credit proves to be highly advantageous in enhancing resource utilization and efficiency. Furthermore, Shapiro [19] emphasized that efficiency pertains to the effective exploitation of resources in order to provide a specific output, rather than solely focusing on the speed at which input translates into output. The operation of a farm business, regardless of whether it adopts modern or traditional methods, entails the utilization of resources to generate output. The input-output process of farming activity holds significance in a minimum of four key problem domains. The topics encompassed in this study are the domain of income distribution, the allocation of resources, the interplay between stocks and flows, and the assessment of efficiency [20].

The Tanzanian government, over a series of operations, has implemented policies and initiatives with the objective of enhancing the commercialization of the traditional beef cattle farming industry in Tanzania. The effort intended to ensure that the industry effectively promotes household food security and economy, thus poverty reduction among traditional beef cattle farmers [12]. The strategies implemented to promote the commercialization of the industry encompass several measures such as facilitating the connection between farmers and lucrative markets (market information access), providing subsidies for agricultural inputs, and enhancing farmers' access to funds and veterinary services [21, 22]. Among the strategies mentioned above, the market information access program implemented by the ministry of livestock and fisheries (MLF) and the ministry of trade (MT), namely, the Livestock Information Network Knowledge System (LINKS), has been gathering, analyzing, and disseminating livestock market information to beef cattle farmers [23]. The initiative intended to connect beef cattle farmers with a profitable market to boost market participation and maximize profits, hence promoting the commercialization of the traditional beef cattle industry. Furthermore, it is worth noting that the government actively promotes the practice of reducing the size of cattle herds among farmers. Additionally, farmers are encouraged to settle on designated territory specifically assigned for grazing purposes. Moreover, there is an emphasis on the fattening of beef cattle prior to their sale, which is considered a value-addition strategy [12, 21, 22].

Despite the concerted efforts made by the government to promote the commercialization of the traditional beef cattle farming industry, a significant number of traditional beef cattle farmers still face impoverished living conditions. Furthermore, the industry's contribution to the national Gross Domestic Product (GDP) remains considerably below its anticipated potential, as evidenced by several sources [9, 16, 23]. Based on a study conducted by the Ministry of Livestock and Fisheries [9], it is evident that the beef cattle industry makes a relatively insignificant contribution to the annual revenue of traditional beef cattle producers, resulting in a poverty rate of 22% among these farmers. This assertion strongly indicates that traditional beef cattle farmers derive minimal or negligible economic benefits (poor profit maximization) from engaging in beef cattle farming. This is viewed as the root of a decline in profitability, viability and profit efficiency. These shortfalls raise concerns regarding the current commercialization level of traditional beef cattle production in Tanzania, even when the industry is experiencing favorable commercialization policy implementation. The traditional beef cattle farming industry in Tanzania still has huge potential to boost income from and supply of beef cattle, both domestically and internationally; farmers' profit maximization is most likely the most effective strategy for achieving this goal. Undoubtedly, traditional beef cattle farmers’ profit maximization is believed to be critical to the commercialization of the traditional beef cattle farming industry and a transformation toward the alleviation of poverty among rural farming households in Sub-Saharan Africa (SSA), including Tanzania [24]. However, traditional beef cattle farmers are well known for their low-profit maximization. Thus, it is necessary to develop interventions to help traditional beef cattle farmers become more competitive and successful in profit maximization to ensure better household revenue, food assurance, and the country's economic growth, thereby alleviating poverty.

Empirical evidence in the country shows that research on beef cattle profitability and value chain strength is being undertaken as an indicator to assess commercialization limitations for further commercialization of the traditional beef cattle industry in Tanzania [21, 25-29]. Nevertheless, there is a lack of research on the level of profit efficiency (PE) and its determinants. This research gap is limiting the development of strategies to optimize the commercialization of the traditional beef cattle farming industry in Tanzania. Traditional beef cattle farmers in Tanzania must enhance the profit efficiency (PE) of beef cattle production to increase output and satisfy the growing demand. In general, an enhancement in profit efficiency would benefit the welfare of farmers, thereby reducing their poverty and food insecurity. This study, thus, sought to gain empirical evidence on the level of profit efficiency (PE) among traditional beef cattle farmers in Tanzania. Notably, to determine if farmers are profitable along the profit frontier (efficient) by generating the stochastic frontier profit function to capture the profit inefficiency effects to identify the areas of intervention for further optimizing the commercialization of the industry to ensure better household income, food security, and the country's economic growth, thereby alleviating poverty among farmers. Specifically, this study was designed to: (i) assess the socioeconomic characteristics of traditional beef cattle farmers; and (ii) measure profit efficiency and its determinants in traditional beef cattle farming.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The research was carried out in the Meatu District, located inside the Simiyu Region. The Simiyu Region situated in the northern portion of Tanzania and southeast of Lake Victoria. This district is predominantly engaged in traditional beef cattle farming, which serves as its principal economic pursuit. The Simiyu Region is characterized by a substantial beef cattle population, making it one of the regions that significantly contribute to the overall national beef cattle herd stock. The territory under consideration encompasses an anticipated population of 1,584,157 individuals. It is further projected to accommodate a total of 1,512,911 beef cattle, over an area of 25,212 square kilometers. The research area encompasses a population of 299,619 individuals, with an estimated count of 495,890 beef cattle inside its boundaries. The annual precipitation in Meatu District has a variation between 600 mm and 900 mm, while the temperature ranges from 18°C to 31°C. In general, it can be observed that around 80% of the total land area is dedicated to grazing purposes, while the remaining 20% is allocated for agricultural production and human settlements [6].

2.2 Sampling Procedures for Traditional Beef Cattle Farmers

The research employed a multi-stage stratified sampling methodology to ascertain participants from the population of beef cattle farmers. The process of selecting interviewees at various stages of the study utilized a combination of purposive and random sampling techniques. Stratified random sampling is a method that involves dividing the population into distinct subgroups or strata based on common features [30]. The strata utilized in this study consisted of the five primary regions and their respective districts that are involved in beef cattle production. Subsequently, a single region, namely Simiyu, was selected at random from the pool of five regions. In a deliberate manner, the district of Meatu was specifically chosen from among the five districts due to its status as the primary producer of beef cattle in the region. Three villages, namely Mwambegwa, Mwambiti, and Nkoma were picked at random within the research district. The present study focused on a population of traditional beef cattle farmers, consisting of 24,139 individuals. To establish a representative sample, Slovin's method was employed, resulting in a sample size of 393 interviewees [31] as;

$$n = \frac{N}{1+Ne^2} = \frac{24{,}139}{1+24{,}139\,(0.05)^2} = 393.48 \approx 393 \qquad (1)$$

In this context, N represents the size of the population being studied, n denotes the size of the sample being collected, and e signifies the level of tolerance for error. The selection of participants from each hamlet (stratum) was chosen by using the percentage proportion, as shown in Table 1.

2.3 Data Collection Methods

This study utilizes primary cross-sectional data. Traditional beef cattle producers in the Meatu District of the Simiyu Region were surveyed using structured questionnaires (see supporting information S1and S2) and interviews to obtain primary cross-sectional data from 10th January to 15th March, 2023. A pilot study was conducted to acquire additional information and familiarize researchers with the study site. Pre-testing of questionnaire items was conducted under conditions as near as possible to the data collection procedure, with prospective participants as close as possible to the samples taken. As a consequence, 50 traditional beef cattle producers were used to pre-test the survey questions in order to evaluate the instrument's validity and reliability. On the basis of the pilot study, revisions were made to the interview and questionnaire instructions, with questions being updated, removed, and reorganized in an effort to make them more straightforward and understandable. Additionally, the study included face-to-face interviews as a means to elucidate inquiries and elicit detailed responses from participants. According to Bateman et al. [32], face-to-face interviews have been found to provide a higher response rate, typically exceeding 70%. Additionally, these interviews allow for the utilization of reference materials and facilitate the collection of diverse information.

2.4 Conceptual Framework

The profit efficiency (PE) of traditional beef cattle farmers was assessed using Dorfman Robert's 1964 production economics theory. The theory describes how a beef cattle farming business determines how many commodities to sell and how much labor, raw resources, and services to utilize. The theory also explains how the prices of commodities (beef cattle) relate to productive factor prices (variable costs). Dorfman Robert [33] classifies business decisions (beef cattle production) as cost reduction and profit maximization. In general, this study is based on the idea that the way inputs and outputs move on the market is a key factor in farm profit efficiency. The study intended to ascertain the extent to which these elements, instead of just farm characteristics, influence farmers' profit efficiency from traditional beef cattle farming. Fig. 1 also shows the relationship between the determinant (independent) variables and the dependent variable in the study, as well as how the high level of profit efficiency (profit maximization) for farmers is supported by some externalities. Fig. 1 illustrates that maximizing profit efficiency depends on minimizing production and marketing expenses and making the best use of a farm's available resources, as well as optimizing the positive impacts of profit inefficiency variables on profit efficiency. The profit inefficiency variables, also known as socioeconomic characteristics, include a farmer's age, education level, household size, farming experience, off-farm income, access to farm credits, access to veterinary services, access to market information, cooperative membership, cattle fattening practice, and distance to market. As a result, the theory helps traditional beef cattle farmers decide how to allocate limited resources, set prices, and select the optimal combination of inputs to maximize profits. Hence, the expected outcomes are a reduction in poverty among farmers, an increase in the production of high-quality cattle and meat, country economic growth, and an increase in foreign direct investment (FDI).

2.5 Analytical Methods

The first description of the primary data analysis focused on descriptive approaches. The subsequent portion of this study centers on the various estimating methodologies employed in empirical models to examine the profit efficiency (PE) of traditional beef cattle farmers. The models included in this study encompass the Cobb-Douglas stochastic frontier profit function model, as well as the Heckman treatment effect model, which is utilized for the purpose of conducting robustness checks. The next section provides a more comprehensive description of the aforementioned analytical methodologies:

Table 1. **Percentage proportion and sample size**

District	Villages	Population	Percentage Proportion	Sample
Meatu	Mwambegwa	8,190	33.93	133
	Mwambiti	7,943	32.91	129
	Nkoma	8,006	33.17	130
Total		24,139	100	393

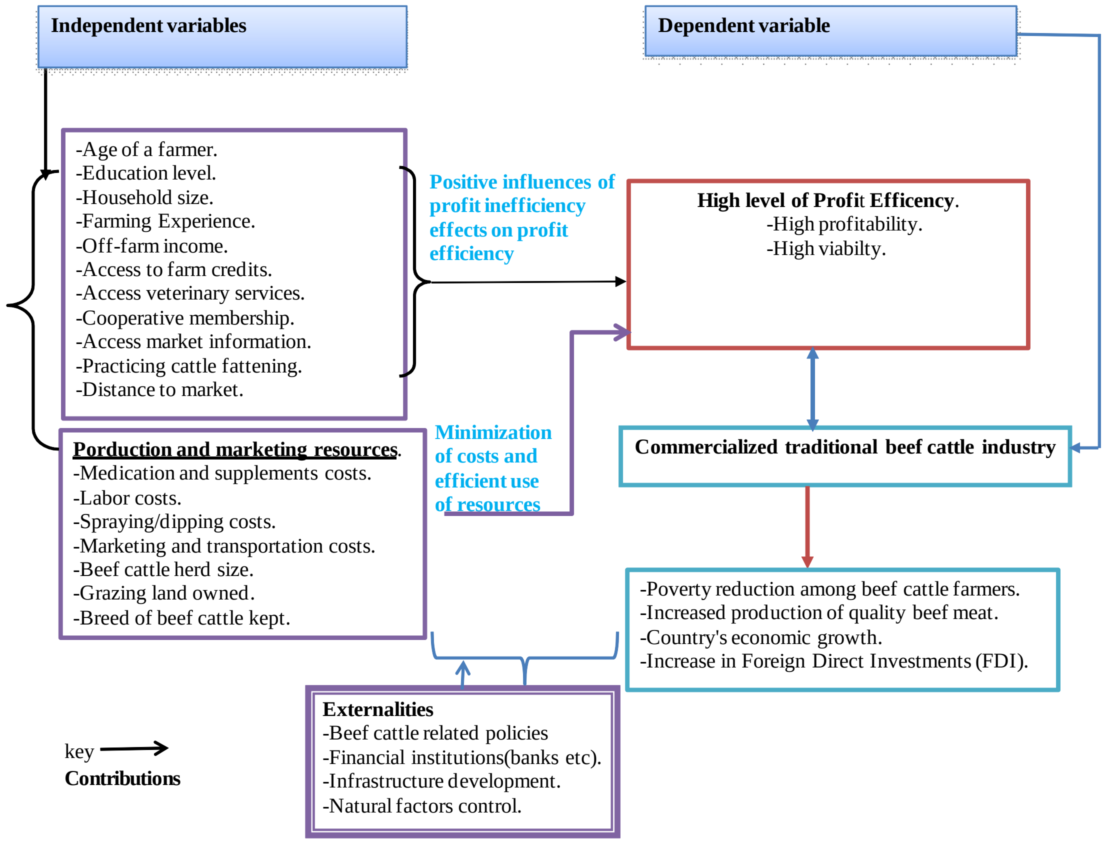

Fig 1. Conceptual framework

2.5.1 Descriptive and inferential analytical methods

The study's parameters were analyzed using both descriptive statistics (mean, median, mode, range, frequency distribution, percentage distribution, and standard deviation) and inferential statistics (independent t-test, chi-square test).

2.5.2 Stochastic frontier profit function model estimation strategy

The stochastic frontier profit function model was used to examine the profit efficiency (PE) and its determinants in beef cattle production among traditional beef cattle farmers within the context of the market information access program. The profit efficiency in this study which in a profit function framework is defined as the profit gained by operating on the profit frontier while taking farm-specific costs and factors into account. While profit inefficiency in this case is viewed as a loss of profit due to not performing on the frontier [34]. This gives beef cattle farmers more information that can help them be more efficient. Profit efficiency assessment contributes to the creation of sensible economic policy for profit maximization among farmers.

Stochastic Frontier analysis (SFA) has been extensively used in modeling efficiency across disciplines [35-37], pioneered the frontier analysis technique, which has since been frequently employed in profit efficiency investigations [35]. Two types of frontier functional forms are commonly used for efficiency estimation in literary works. According to Coelli et al., [38], these are data envelopment analysis (DEA), a non-parametric technique, and stochastic frontier analysis (SFA), a parametric technique. All such techniques estimate the firms' technical, cost, and profit efficiency concerning the efficiency frontier. Besides, both systems can produce highly consistent results, but each has pros and cons depending on the application [39]. The SFA technique requires that a functioning firm be specified for the frontier production (or profit) function, whereas the DEA technique employs linear programming to build a piece-wise frontier that enfolds all firm observable. In econometric research, the DEA's failure to assess the most efficient decision-making unit is highly concerning. Notably, the DEA technique has the benefit of allowing several inputs and outputs to be examined at the same time, as well as allowing inputs and outputs to be measured utilizing various units of measurement. Yet, the major advantage of SFA over DEA is that it accounts for measurement errors and other noise in the data. This concept is critical for analyses of farm-level data in undeveloped countries like Tanzania because data typically contain measurement errors. The DEA's incapacity to investigate the influence of random factors on efficiency scores severely limits its usefulness since it yields cautious outcomes. The SFA technique is used to estimate the frontier production (or profit) function as well as an inefficiency model at the same time, with inefficiency effects defined as a function of other factors [40]. It efficiently establishes the connection between output and input levels, as well as decomposes the error term into discrete components indicating random errors and inefficiency. Because of the aforementioned benefits, the SFA has been used in several profit efficiency studies. Most research used the SFA approach because of its ability to show how random effects and other errors may influence deviance in the production (profit) function, resulting in inefficiency. As a result, the current study used the traditional one-step version of stochastic frontier analysis (SFA) to model the profit efficiency (PE) of traditional beef cattle farmers in Tanzania.

The stochastic frontier profit function involves a stochastic term (described further below) that reflects unpredictable shocks that affect the farmer [41]. Every farmer is subjected to distinct shocks; however, researchers believe that the shocks are randomized and defined by a universal distribution [41]. Several aspects, including profitability, input, and output quality, network features, occupancy form, regulatory changes, and managerial attributes, all have an impact on the surroundings in which production occurs [42]. As per Kumbhakar [43], there are two approaches to dealing with these problems. Firstly, they may be included as controlling factors in the model since they do not affect the efficiency but rather the pattern of technology by which traditional inputs are transformed into products [43]. The alternative is to link variances in calculated efficiency to variations in external factors [43]. Yet, it has been claimed that a profit function method for measuring efficiency may not be adequate when farmers face varied prices and have varying production factors [44]. As a result, stochastic normalized profit function models were used to directly estimate farm-level profit efficiency [45, 46]. Hence, applying the stipulations of Aigner et al., [36] and Meeusen and Van Den Broeck [37], including the stochastic term in the stochastic profit function, yields the standard version of the stochastic frontier profit function formulation shown below:

$$Y_i = f(X_i, \beta)\ exp\ (v_i - u_i) \quad (2)$$

Where Y_i is the normalized profit (gross margin) of the i^{th} sampled traditional beef cattle farmers, defined as gross revenue minus variable costs divided by beef cattle price, f is a suitable profit function (e.g Cobb Douglas, translog, etc, to be specified later in this section), While X and β's signify a $kx1$ vector of normalized input costs and unknown parameters to be estimated, respectively. Moreover, the random error component is denoted by $v_i \sim N\ (0,\ \delta v^2)$, whereas the inefficiency error term is denoted by $u_i \sim N\ [f\ (\mu,\ \alpha),\ \delta u^2]$, which denotes a profit deficit from the maximum achievable. Under this instance, u_i represents inefficiency, and this corresponds to the half-normal half-normal model that serves as the foundation for the stochastic frontier model [47]. Furthermore, the random variables are believed to be independent and identically distributed with zero means, and independent of the u_i; they depict explanatory variables beyond the control of the sampled farmers, such as inclement weather, bushfires, price inflationary pressures, natural disasters, measurement errors, and so on. The u_i, which is anticipated to take into account profit inefficiency, is believed to be a non-negative random variable with independent and uniform distribution. It indicates the extent by which the observable individual falls short of achieving the optimal level of profit (that operates outside the frontier). If $u_i = 0$, the farmer is efficient and functioning along the profit frontier under market circumstances and the number of fixed factors; if $u_i > 0$, the farmer is profitably inefficient, yielding a profit that is lower than the possible optimum. Profit inefficiency, therefore, exists on such a farm. The projected value of profit efficiency for every farmer is $exp\ (-u_i)$ per observation. The constant variance of the profit inefficiency term u_i is denoted by δu^2. Considerably, the model's variance $\delta u^2 = \delta^2 v + \delta^2 \mu$ estimates the overall deviation of profit from the frontier that may be attributed to profit inefficiency, [48]]. There is additionally a location parameter μ for the inefficiency error component. The position parameter is affected by exogenous variables, whereas u has a positive truncated normally distributed. Namely, $\mu = \alpha z$, where α is a $1 \times p$ vector of parameters that have to be estimated. Thus, the determinants of profit efficiency can be determined using the normalized technique by using the profit frontier in Equation 3. Besides, as per Battese and Coelli [49], the standard equation for inefficiency impacts is as follows:

$$u_i = f(\mu_i, \alpha) \quad (3)$$

Essentially, each farmer's profit loss can be estimated as the product of the inefficiency index (π) and the maximum possible profit, given farm-specific costs and fixed factors. As a result, the farm-specific inefficiency index is provided by:

$$\pi = [1 - \exp(u_i)] \quad (4)$$

Hence, the inefficiency framework integrating farm and household factors can be described as:

$$\mu_i = \alpha_0 + \alpha_1 X_{1i} + \alpha_2 X_{2i} + \ldots\ldots + \alpha_k X_{ki} + Z \quad (5)$$

Here, X_i's are the independent variables of the stochastic profit function, including the age of the family head, farming experience, household size, herd size, education, and so on, and z is the peculiar inefficiency aspect, which includes aspects such as seasonal changes, disease and pest infestations, and prices that are unique to a specific farm.

Nevertheless, to correctly detect the presence of any sort of profit inefficiency in the production system (profit maximization system), the variance factors of the entire framework must be determined throughout the SFA estimation technique. The variance factor is determined in the following way:

$$\delta^2 = \delta_u^2 + \delta_v^2; \gamma = \frac{\delta_u^2}{\delta_u^2 + \delta_v^2} = \frac{\delta_u^2}{\delta^2} \quad (6)$$

When the total variance is δ^2, the gamma (γ) is utilized to discover inefficiency using the one-step (efficiency investigation) SFA approach [49]. Gamma (γ) has a value between 0 and 1. Whenever the value of gamma is 0, it indicates that there is no inefficiency in the production system, thus indicating that the SFA technique is less desirable than the OLS approach. Whenever gamma is 1, divergence from the frontier is solely attributable to inefficiency impacts. Besides, a gamma score between 0 and 1, therefore $(0 < \gamma < 1)$, indicates that the deviations are driven by both inefficiency and random variables.

Eventually, PE, or profit efficiency of the i^{-th} farmer, is stated as the ratio of expected profit to forecasted maximum profit for the best farm and is written as:

$$PE_i = \frac{Y_i}{Y_i^*} = \frac{f(X_i, \beta)\exp(v_i - u_i)}{f(X_i, \beta)\exp(v_i)} = \exp(-u_i) \quad (7)$$

Where Y_i is the actual profit (observed profit) with an inefficiency element, Y_i* is the frontier profit without an inefficiency element. The anticipated profit efficiency estimates lie between 0 and 1 or are occasionally expressed as a percentage. It is important to note that maximum likelihood approaches are used to estimate the parameters of stochastic frontier models [36].

Furthermore, notwithstanding the apparent limitations of the Cobb- Douglas (CD) functional form, it was employed in this study to determine the profit frontier. Given the smaller sample size and its relevance to beef cattle farming in Tanzania, the CD function was chosen over the translog function. Nevertheless, the translog function needs a greater number of degrees of freedom to achieve precise estimations, as it permits as many factors in the method. The CD profit function models the profit trends of surveyed farm owners in the study area using the first-order estimation of whatever unknown function. Taylor & Shonkwiler [50]] established that the production technology can be accurately addressed by the CD profit function given that we are not attempting to identify the form of the production technology but instead measuring its efficiency. As per the research of Kopp and Smith [51], the functional form design has a noticeable but negligible effect on efficiency estimations. This has increased the prevalence of the CD functional type in productivity and efficiency research [52]]. This literature study suggests that without doing a test of the hypothesis, it is impossible to determine which is more effective. In this study, the study performed a hypothesis test to determine which hypothesis was more plausible. The likelihood ratio test (LR Test) [53] can be employed to examine the model specification of the stochastic production frontier. The null hypothesis of the LR test [54] is that all translog-related interactions and second-order terms are equal to zero.

Thus, the likelihood ratio test was used to choose the Cobb- Douglas stochastic frontier profit function as the optimal fit for the data over translog. Hence, the Cobb- Douglas stochastic frontier profit function is denoted as follows:

$$InY_i = \beta_0 + \beta_i \sum_{i=1}^{n} InX_i + (v_i - u_i) \quad (8)$$

Where InY_i is the normalized beef cattle profit in natural log. InX_i represents the vector of n^{th} classical variable costs of beef cattle production and marketing logistic costs such as medication and supplements, labor for herding, spraying/dipping for eradicating external parasites, grazing land owned, beef cattle herd size, local breed beef cattle as well as marketing and transportation costs. The remaining components have previously been described. Apart from other variables influencing inefficiency, access to market information is our test variable to see whether the established market information inclusion program among farmers affects profit efficiency. The best way to determine the links between the market information inclusion (access to market information) program and increased profit efficiency is to incorporate it into an econometric model (profit inefficiency function model). Thus, the profit inefficiency function model *(u_i)* is expressed as follows:

$$u_i = \alpha_0 + \alpha_1 AMI_i + \sum_{k=0}^{1} M_{ik}\alpha_k + z_i \quad (9)$$

Here u_i*'s* are non-negative random variables related to profit inefficiency and are considered to be identically and independently distributed using a truncated normally distributed, z_i denotes a random error term in the profit inefficiency function model, and α is a vector of undetermined coefficients that need to be estimated simultaneously using equation (9). Apart from access to market information (AMI_i), the vector M_i represents the other determinants of profit inefficiency, which are the socioeconomic characteristics of the farm. These are the determinants of the farm's profit inefficiency such as the age of a farmer, educational level, household size, farming experience, off-farm income, access to veterinary services, access to credits, cooperative membership, practicing beef cattle fattening, and distance to the commonly used market.

2.5.3 Cobb-douglas stochastic frontier profit function model specification strategy

Parameters of the stochastic production frontier model were estimated in Frontier 4.1 by maximum likelihood estimation (MLE) [55]. Notably, no issues with multicollinearity across continuous and discrete factors were identified using VIF and CC tests prior to looking at the profit frontier parameter estimates and variables influencing the inefficiency of traditional beef cattle farmers in Tanzania. In addition, the function model was validated using a series of hypothesis tests as described below.

The first hypothesis tests whether or not the inefficient part of the mixed error term of the stochastic frontier framework is present. This may be utilized to determine whether the two models—the average profit function (OLS) or the stochastic frontier model (SFM)—provide a better match to the data. The derived generalized likelihood-ratio $LR = 2[lnL(H_0)lmL(H_1)]$ statistics for assessing if the frontier does not influence profit inefficiency is LR = -2*(229.49914+199.91773)= 58. At the 5% level of significance, this number (58) exceeds the crucial x^2 (5%, 1) value of 3.84. With the suitable ordinary least squares (OLS) production function, the null hypothesis was rejected; indicating that the stochastic frontier profit function adequately represented the data. Thus, the data for this study are best explained by the stochastic frontier approach.

The second hypothesis tested concerned the optimal data functional form, namely the choice between the Cobb-Douglas and trans-log production functions. This requires calculating λ, the likelihood ratio by using the formula given below [56]:

$$\lambda = -2(l_R - l_u) \quad (10)$$

Here l_R was the likelihood function of the Cobb-Douglas model (indicating the null hypothesis H_0) and l_U was the likelihood function of the translog model, representing the alternative hypothesis (H_I). Functional form selection is based on the calculated likelihood ratio. The critical value of x^2 at a 5% significant level was calculated to be 33.78, and the Log-likelihood ratio was determined to be *(LR = 2*(198.93751+-186.42384) = 29.42)*. The result is a confirmation of the null hypothesis, which asserts that the coefficients of the interaction terms in the trans-log formulation are all equal to zero. This indicates that the Cobb-Douglas functional form is a good representation of the data. Thus, the profit efficiency (PE) of sampled traditional beef cattle farmers was calculated using the Cobb-Douglas functional form (see equation 10).

This study also tested the third null hypothesis, which states that the profit inefficiency on farms is unaffected by the socioeconomic factors incorporated into the inefficiency model. This hypothesis is focused on determining whether or not profit inefficiency effects exist in the model. This section is the core of this purpose since it examines whether the traditional beef cattle farmers under investigation are profitable along the frontier (efficient) as opposed to showing the need to explore the elements that contribute to lowering their inefficiency. That is, if inefficiency effects were irrelevant, we wouldn't have to generate a stochastic frontier model, instead using the mean profit function through OLS, as the farmers ought to be at the profitable efficiency frontier. The value of the Log-Likelihood function *{LR = 2[234.35856+-186.42384 = 49.76]}* was used to determine the inefficient impact. At the 5% level of significance, the *LR* score of 49.76 calculated was more than the critical value of 19.42, showing that the null hypothesis (H_0), which asserts that all independent variables are simultaneously equal to zero, was rejected. Thereby, these characteristics also provide insight into why the profit efficiency of sample households differs.

Thus, the following is the explicit Cobb-Douglas stochastic frontier profit functional model for this study:

$$InY_i = \beta_0 + \beta_1 InX_{1i} + \beta_2 InX_{2i} + \beta_3 InX_{3i} + \beta_4 InX_{4i} + \beta_5 InX_{5i} + \beta_{6i} InX_{6i} + \beta_{7i} InX_{7i} + (v_i - u_i) \quad (11)$$

Here;

Y_i = Normalized profit in the US $ calculated as total revenue less variable costs divided by the market price for beef cattle,
X_i = Cost of medications and supplements (US$).
X_2 = The cost of labor for herding (US$).
X_3 = The cost of spraying/dipping to eliminate external parasites (spraying/dipping costs) (US$.
X_4 = Marketing and transportation costs (US$).
X_5 = Grazing land owned (ha)
X_6 = Beef cattle herd size (heads)
X_7 = Local breed beef cattle (heads)
β_0 = constant
β_1,. . .,.. β_5 = coefficients to be estimated
u_i = Profit inefficiency
v_i = Systematic error component

Moreover, based on Battese and Coelli [49] expanded the stochastic frontier model and suggested that inefficiency can be described as a linear function of a collection of explanatory factors that represent a firm's attributes. Thus, the profit inefficiency model was developed from general equation 11 to evaluate the impact of observable socioeconomic and farm business explanatory factors on the profit inefficiencies of farmers. Thus, the profit inefficiency (u_i) model is specified as follows:

$$u_i = \alpha_0 + \alpha_1 AMI_{1i} + \alpha_1 M_{1i} + \alpha_2 M_{2i} + \alpha_3 M_{3i} + \alpha_4 M_{4i} + \alpha_5 M_{5i} + \alpha_6 M_{6i} + \alpha_7 M_{7i} + \alpha_8 M_{8i} + \alpha_9 M_{9i} + \alpha_{10} M_{10i} \quad (12)$$

Here;

U_i = Profit inefficiency.
AMI_1 = Access to market information program
M_1 = Age of a farmer (Years).
M_2 = Educational level.
M_3 = Household size.
M_4 = Farming experience.
M_5 = Off-farm income.
M_6 = Access to veterinary services.
M7 = Access to farm credit.
M_8 = Cooperative membership.
M_9 = Practicing beef cattle fattening (value addition).
M_{10} = Distance to market.
α_0, α = are parameters that have to be estimated.

Besides, Table 2 provides a summary of the hypothesized signs and descriptions of the independent variables used in equations 11 and 12.

2.5.4 Heckman treatment effect model for robustness check

Access to market information is the variable of interest for determining if the established market information inclusion program has an effect on profit efficiency among farmers. At first, the Heckman treatment effect model is used to examine the impact of market information access on the profit efficiency of beef cattle production. As a robustness check, it also assesses the influence of market information as evaluated by the inefficiency model (Cobb- Douglas stochastic frontier profit function analysis). Following Heckman [57, 58], the method adjusts for bias in sample selection due to unobservable variables. Most crucially, Heckman's treatment effects model is an extension of his two-stage model, with the sole difference being that only the former uses the dependent variable in the selection equation as an exogenous variable in the result equation (treatment effects model). Generalizing the impact of access to market information on profit efficiency is judged biased since not all studied farmers were successful in exploiting market information. There are two sorts of estimating procedures. Initially, a probit model is employed to model the selection equation; next, the projected values of the dependent factor, also referred to as the inverse mills' ratio (IMR), are utilized as a selection control variable. It is utilized as an extra endogenous variable in the resulting formula as a correction for selection bias, hence removing bias from other exogenous variables. Thus, market information access's effect on farmers' profit efficiency is precisely quantified since the treatment condition is an independent variable. The model goes through two phases; the first phase is the probit, which represents the market information inclusion program participation decision. The model is depicted as follows:

$$AMI_i = \beta_0 + \delta_i X_i + \varepsilon_i \qquad (13)$$

Here AMI_i is a dependent latent factor affecting whether or not farmers decide to join a market information inclusion program (access to market information). This variable is treated as a dummy: 1 means "yes" (involvement), and 0 means "no" (non-involvement). The factor *"X"* stands for a collection of explanatory factors that shape how farmers are decided to participate in the market information inclusion program. Such explanatory factors include the age of a farmer, educational level, household size, farming experience, off-farm income, access to veterinary services, access to credits, cooperative membership, practicing beef cattle fattening, and distance to the commonly used market. In addition, ε_i represents the error term and δ_i represents the parameters to be estimated. Hence, the outcome equation appears as follows:

$$Y_i = \beta_0 + \delta_i X_i + \alpha_i AMI_i + \varepsilon_i \qquad (14)$$

Here Y_i represents profit efficiency, α_i measures market information impacts on the outcome variable (called "market information access participation" in the second stage outcomes). To adjust for self-selection biases in the actual equation 14, an IMR represented by the symbol λ was produced and included as a further independent factor. The IMR formulation procedure is as follows:

$$\lambda = \frac{\emptyset(-\delta_i X)}{1 - \Phi(\delta_i X)} \qquad (15)$$

In where $\emptyset$ and Φ account for the normal density and distribution functions, respectively. The outcome, after including the *IMR (λ)*, in Equation 15, is:

$$Y_i = \beta_i + \delta_i X_i + \alpha_i AMI_i + \gamma_i \lambda_i + \varepsilon_i \qquad (16)$$

Table 2. Hypothesized signs and descriptions of the independent variables used in models 11 (stochastic frontier profit model) and 12 (inefficiency effect model)

Variables	Measurements	Hypothesized signs
Stochastic frontier profit model		
Cost of medications and supplements	US dollars (US$)	-
The cost of labor for herding	US dollars (US$)	-
The cost of spraying/dipping parasites	US dollars (US$)	-
Marketing and transportation costs	US dollars (US$)	-
Grazing land owned	Hectares (ha)	+
Beef cattle herd size	Number of beef cattle	+
Local breed beef cattle	Number of local breeds	-
Inefficiency effect model		
Age of a farmer	Age in years	+
Educational level	Years of schooling	-
Household size	Number of members	-
Farming experience.	Years of farming	-
Off-farm income	US dollars (US$)	-
Access to veterinary services	If 0=No,1=Yes	-
Access to farm credits	If 0=No,1=Yes	-
Access to market information	If 0=No,1=Yes	-
Cooperative membership	If 0=No,1=Yes	-
Beef cattle fattening (value addition)	If 0=No,1=Yes	-
Distance to market	Kilometers	+

Where γ_i represents the estimated IMR coefficient. X_i denotes explanatory factors including farmer age, education, household size, farming experience, non-farm income, veterinary service availability, credit availability, cooperative membership, fattening beef cattle, and distance to the typical market. The remaining components have previously been defined. A coefficient of the IMR that is statistically significant suggests self-selection, whereas a coefficient that is not statistically significant demonstrates the absence of sample selection. Ignoring the inclusion of the IMR will result in biased results from Equation (14) [57]. Hence, the addition of the selectivity component renders the coefficient α_i (indicating the impacts of the treatment variable on the dependent variable) unbiased, but inefficient due to the heteroscedastic nature of the error terms ε_i [58]. The issue of heteroscedasticity can be solved by employing bootstrap standard errors or by resampling the data. Both of these options are available. The STATA software package, however, which was utilized in the process of generating the estimations, makes an automated adjustment for the bias in the standard errors [59].

3. RESULTS AND DISCUSSION

3.1 Socioeconomic Characteristics of Traditional Beef Cattle Farmers

Table 3 shows that males dominated beef cattle production among traditional beef cattle farmers. This indicates gender disparity: females should be encouraged to engage in beef cattle farming. Women are also responsible for farming and food processing, as men migrate from rural to urban centers in search of employment [60]. The analysis also revealed that 67.9% of farmers had primary education, while only 4.1% had secondary education. The remaining 28% of farmers had no formal education. These findings revealed that most farmers had a low level of education. This is because, in traditional farming households, the educational value is replaced with beef cattle; in other words, you are respected by the total number of beef cattle you possess rather than the educational level achieved. Thus, traditional beef cattle farmers should be provided with tailor-made training and education to promote the commercialization of the traditional beef cattle industry. Education improves one's ability to observe product quality, effectively negotiate prices, and access available market information for profit maximization. People with high levels of education should be encouraged to invest in beef cattle production to boost quality production and marketing. Findings in this study also show that 61.3% of farmers had access to market information. This may suggest that farmers were more exposed to market information. This was due to the presence of the market information inclusion program implemented by the government. The program implemented by the Ministry of Livestock and Fisheries and the Ministry of Trade, namely the Livestock Information Network Knowledge System (LINKS), financed by USAID, which gathers, analyzes, and disseminates livestock market information, is being used to conduct the increased market information inclusion program among beef cattle farmers. Obtaining accurate market information is an essential factor for the farmers to offer beef cattle at a profitable price, hence profit maximization. Furthermore, this study has shown that only 4.6% of farmers had access to farm credit. This implies that farmers had poor access to farm credits. Beef cattle farmers need suitable and convenient arrangements as well as assistance in the establishment of a marketing system for securing farm credit. Farm credit is important for investing in beef cattle production and marketing activities, thus boosting beef cattle productivity and profitability [61]. Regarding access to veterinary services, results show that 32.6% of beef cattle farmers had access to veterinary services. Access to veterinary services should be improved by reducing the cost of acquiring consultations necessary for improved beef cattle production. Results in this study also revealed that only 14.8% of beef cattle farmers were engaged in farmer's cooperatives. This indicates limited involvement in cooperative activities among farmers. Incentives should be set forth to attract farmers to join cooperatives. Cooperatives help beef cattle farmers mobilize resources, share market information, improve their bargaining power and access to farm credits, promote their products and services, and reduce the cost of production through economies of scale [61].

The study also found that the average age of farmers who raise beef cattle was 53.73 years. This indicates that beef cattle farmers were in the active age group of the labor force, which is important in the adoption of beef cattle production technologies that enhance productivity and profitability for the economic sustainability of beef cattle production. The average household size among beef cattle farmers was 13.11 people. This indicates a higher labor force potential for beef cattle production among beef cattle farmers. Efficient use of family labor promotes beef cattle productivity, thereby enhancing market participation and profitability. Results in this study also show that beef cattle farmers had 24.14 years of farming experience. Beef cattle farming experience increases beef cattle productivity through the acquisition of skills and knowledge, thereby increasing the farmers' probability of increasing profitability and efficiency [61, 62]. Furthermore, the results revealed that beef cattle farmers had an average of 53.50 beef cattle herd sizes. Considering the large beef cattle population in Tanzania at the national level, the size of the beef cattle herd at the household (farmer) level is also large enough to support stable and sufficient commercialization. The study results also revealed that the average off-farm income among beef cattle farmers was 1,169 US dollars per year. Apparently, off-farm income increases farm productivity if reinvested in beef cattle production, thereby increasing the chance for beef cattle farmers to maximize income through selling highly valuable beef cattle. The average grazing land owned by beef cattle farmers was 38.35 ha. Grazing land availability is important for beef cattle productivity and profitability, which enhances the economic benefits and efficiency of beef cattle production [29]. The study findings also show that the characteristics of the beef cattle flocks, such as cows, bulls, and heifers, were on average 23.95, 11.43, 8.89, and 9.59, respectively, among farmers. These factors are concerned with beef cattle herd dynamics marked by increased beef cattle productivity, hence promoting profitability, viability, and profit efficiency among beef cattle farmers.

Table 3. Socioeconomic characteristics of traditional beef cattle farmers

Categorical Variables (N = 393)				
Variables	**Frequency**		**Percentage**	
Gender				
Male	393		100.0	
Education Level				
No. education	110		28.0	
Primary educ.	267		67.9	
Secondary educ.	16		4.1	
Access to market information				
Yes	241		61.3	
No	152		38.7	
Access to Credits				
Yes	18		4.6	
No	375		95.4	
Access to Veterinary Services				
Yes	128		32.6	
No	265		67.4	
Membership to Cooperatives				
Yes	58		14.8	
No	335		85.2	
Continuous Variables (N =398)				
Variables	**Mean**	**Max.**	**Min.**	**Std.Deviation**
Age of a farmer	53.73	105.0	20.0	15.7
Household Size	13.11	40.0	1.0	6.8
Farming Experience (years)	24.14	80.0	5.0	15.0
Off-farm income (US$)	1,169	2,532	253.0	456.2
Grazing Land Owned (ha)	38.35	60.0	0.8	6.6
Beef cattle herd size (heads)	53.50	200.0	13.0	30.2
Cows owned (heads)	23.93	53.2	2.0	29.5
Bulls-owned (heads)	11.43	28,1	3.0	30.6
Steers-Oxen-owned (heads)	8.89	18.9	0.0	49.4
Heifers owned (heads)	9.59	24.5	2.0	52.6

Source: Estimates based on Author's field survey data

3.2 Profit Efficiency and its Determinants of Beef Cattle Farming among Traditional Beef Cattle Farmers

3.2.1 Maximum likelihood estimates of cobb-douglas stochastic frontier profit function among traditional beef cattle farmers

The results of the study's maximum-likelihood estimates (MLE) method are shown in Table 4. This method was used after the stochastic frontier profit function analysis was done. Estimates of the frontier parameters and the factors that lead to profit inefficiency are shown separately to make things easier to understand. The analysis of the SFA data used in the study was performed almost entirely with the help of the Frontier 4.1 software. The model's specifications, which were fully explained in subsection 2.5.2, show that it can be used in a wide range of situations. Having decided to go with the alternative hypothesis, which states that profit efficiency in the studied area is influenced by profit inefficiency, the null hypothesis, which was rejected, states that there is no evidence of inefficiency. This choice is validated by the significant log-likelihood ratio test (LR test) with a value of 67.42, which indicates that the inefficiency component, ui, is nonzero and also significant. As per Bravo-Ureta et al., [52], the presence of a significant lambda (λ) value that is greater than zero suggests that the profit efficiency possibility of chosen farmers is considerably impacted by inefficiency. The presumption made regarding the production error terms is supported by the sigma squared (σ2) score of 0.656, which represents the system's total variance. Moreover, Kea et al., [63] agrees that the gamma value (γ) is crucial in deciding whether the ordinary least squares technique (OLS) or stochastic frontier analysis (SFA) should be utilized. The computed gamma value (γ) of 0.73 indicates that the existence of inefficiency in the implemented farming methods, input utilization, or farmer incapability is the cause of 73% of the variation in the chosen farmers' profit from the frontier's specification. Furthermore, random errors account for 27% of the variation found between the profit earned at the frontier and the actual profit acquired by farmers. We can certainly infer that the beef cattle farming system exhibits both random errors and inefficiency since its gamma values range from 0 to 1, which eventually supports the stochastic nature of traditional beef cattle farming. In light of these inferences and diagnostics from the stochastic frontier profit function analysis, it seems likely that the profit inefficiency factor plays a significant role in understanding farmers' profit levels.

In particular, estimations of the stochastic frontier profit function in Table 4 demonstrate that coefficients of variable costs have a significant negative effect, revealing that the projected normalized profit is convex in variable costs, which suggests that the profit drops as variable costs (cost of medications and supplements, cost of labor for herding, cost of spraying or dipping parasites, and marketing and transportation costs) increase. The cost of medications and supplements, as well as the cost of eliminating external parasites, has a negative coefficient that is statistically significant at the 5% level, reducing the profit efficiency of traditional beef cattle farmers. A negative relationship for medication cost suggests that money spent on medicines has an impact on beef cattle profit efficiency. This is because of the prevalence of several illnesses and parasites in beef cattle farming areas, especially in Tanzania's traditional beef cattle farming, in which beef cattle are raised in a free-range system. The cost of treating beef cattle during a disease epidemic is high [29]. Hence, the best strategy to optimize profits is to create health programs tailored to beef cattle to deal with any possible health concerns [29]. The results are consistent with those of Bahta & Baker [47] and Otieno [64], who both emphasized the importance of health costs in beef cattle production, citing the rising prevalence of illnesses and parasites that require expensive medical interventions, hence diminishing profit efficiency. Moreover, the herding labor estimate coefficient is negative and statistically significant at the 5% level. The sign of the coefficient confirms the cost consequence of hiring labor for herding to beef cattle farms' profit efficiency levels. As per Dillion et al., [65], the cost of hired labor is second only to health care expenses. If profit is to be optimized in traditional beef cattle farming, family labor efficiency must be as high as feasible. Furthermore, the negative sign for marketing and transportation costs implies that increasing these factors likely leads to a reduction in farmers' profit efficiency, which could be attributed to the high transport expenses in the study area. This finding is similar to Nasiru's [66, 67]. Mohammed et al. [67]. Remarkably, the factors highlighted—notably medicine, labor, external parasite removal, and marketing and transportation expenses—emphasize the capital required in the production and trade processes of beef cattle. Marketing expenses, on the other hand, reveal obvious expenses that may obstruct the maximization of profit [61]. Furthermore, at the 5% level of statistical significance, this study indicated that the size of owned grazing land significantly improved the profit efficiency of beef cattle farming. This suggests that as the extent of grazing land owned by beef cattle farmers increases, so does the profit efficiency of beef cattle. This outcome aligns with the findings of Nkadimeng et al., [68]. Besides, at the 5% level, the coefficient on beef cattle herd size is positive and of statistical significance. This means that farmers with vast cattle herds are more profitable, implying economies of scale. The results demonstrate that the profit efficiency of beef cattle increases with increasing herd size. Yet, herd size should be kept to a manageable level since managing larger herd numbers is both time-consuming and resource-intensive, thereby maximizing costs and lowering profit efficiency. As per Koknaroglu et al., [69], higher profit efficiency per beef cattle is reached when there are manageable beef cattle on a particular farm. An efficiently run farm may profitably produce and deliver high-quality goods to the intended market, thereby increasing profit efficiency [70]. In addition, keeping local breed beef cattle was found to be negatively and statistically significant at the 5% level. This means that a 1% increase in the use of local breeds would reduce the farm's profit efficiency by 23.5%. Local-breed beef cattle grow and mature at a slower rate than crossbreds (hybrids), hence reducing profit efficiency for traditional beef cattle farmers. As a result, farmers should be incentivized to acquire and utilize the most improved breed of beef cattle to maximize their profits.

Table 4. Maximum likelihood estimates of stochastic frontier profit function among traditional beef cattle farmers

Variable	Coefficient	Std. Error.	t-stat.
Stochastic frontier profit model			
Constant	3.989	1.468	4.331***
Cost of medications and supplements	-0.521	0.135	-2.331**
Cost of labor for herding	-0.263	0.243	-2.386**
Cost of spraying/dipping parasites	-0.432	0.321	-2.728**
Marketing and transportation costs	-0.285	0.367	-2.678**
Grazing land owned	0.467	0.245	2.826**
Beef cattle herd size	0.038	0.145	0.223**
Local breed beef cattle	-0.235	0.132	-1.145**
Inefficiency effect model			
Constant	4.384	1.027	4.218**
Age of a farmer	0.049	0.156	0.312
Educational level	-0.325	0.087	-2.723**
Household size	-0.062	0.051	1.322*
Farming experience	-0.342	0.178	-3.421**
Off-farm income	-0.214	0.076	-1.612**
Access to veterinary services	-0.173	0.161	-2.433**
Access to farm credits	-0.085	0.110	-2.181**
Access to market information	-0.301	0.201	-2.160**
Cooperative membership	-0.231	0.167	-3.310
Beef cattle fattening (value addition)	-0.341	0.168	-2.257**
Distance to market	0.124	0.021	1.034**
Model Diagnostics			
Sigma U-squared (σ^2)	0.345		
Sigma V-squared (σ^2)	0.243		
Lambda (λ)	1.172*		
Sigma-squared (σ^2)	0.656*		
Gamma (γ)	0.728*		
Log-likelihood ratio test	67.422**		
Mean profit efficiency(PE)	0.49		
Sample size (n)	393		

*Source: Author's field survey data; ***, **, * denote statistical significance at 1%, 5%, and 10%, respectively.*

3.2.2 Distribution of profit efficiency scores among traditional beef cattle farmers

The predicted profit efficiencies of the sampled traditional beef cattle farmers are displayed in Table 5. Using the stochastic frontier profit function, the profit efficiency of traditional beef cattle farmers was calculated to be between 16% and 81%, with an average of 49%. The level of profit efficiency varies greatly across farmers. This indicates that traditional beef cattle farmers in the study area are less profitable (not profit-efficient). So, traditional beef cattle farmers in the study area lose 51% of their profits on average due to technical and allocative inefficiency, as the likelihood ratio test has previously revealed. This suggests that, with the same level of current technology and resources, profits can be increased by at least 51% on average if profit inefficiency variables are adequately addressed, or, to clarify, profits can be increased by up to 51% on average if sufficient efforts are made to enhance overall efficiency. There is still room for farmers to increase their profit efficiency. The best way to do this is to adopt the usage of improved beef cattle breeds since it was seen that all farmers were utilizing beef cattle of local breeds. This indicates that they were not producing the most valuable beef cattle achievable with the resources available. Moreover, frequent interaction with veterinary agencies is also the best strategy to help farmers efficiently and timely allocate beef cattle health care expenditures to produce the most profitable beef cattle at the lowest cost.

3.2.3 Determinants of profit inefficiency among traditional beef cattle farmers

Given that profit efficiency is thought to be low and that profit inefficiency is thought to happen, this study needed to find out what factors affect profit efficiency among traditional beef cattle farmers. For policy changes, it's important to know what causes inefficiency. One way to do this is to look at the relationship between farm and farmer characteristics and the estimated profit inefficiency. This section is covered separately and reiterated here due to its importance in identifying the different circumstances that might prevent farmers from maximizing their profits. This will enable traditional beef cattle farmers to have comprehensive methods and mechanisms to increase their profit efficiency levels for maximizing profits, leading to the firm's commercialization. Notably, section 3.3.1 of Table 4 previously displayed the inefficiency effects model produced as part of the stochastic frontier profit function analysis. However, Table 6 displays the inefficiency model's findings again. These factors in this model are used to identify the drivers of profit inefficiency impacts in beef cattle production instead of the drivers of efficiency impacts. Profit inefficiency factors were hypothesized to describe beef cattle farmers' profit efficiency. When attempting to explain the actual level of profit efficiency of the farmers, the value of the factors in the inefficiency model is of the utmost importance. Generally, parameters in the inefficiency effect model with a negative value indicate that the parameters boost profit efficiency by decreasing inefficiency, while those with a positive value indicating that inefficiency is increasing among beef cattle farmers [71]. Additionally, as per Admassie & Matambalya [72], merely noting that certain farms are profitably inefficient is ineffective until the causes of profit inefficiency are recognized. Thus, Table 6 indicates that eight (8) of the eleven (11) farm-specific variables in the inefficiency effect model statistically significantly contributed negatively to profit inefficiency among traditional beef cattle farmers at a 5% level. Yet another variable with 10% significance. They include access to market information, farming experience, education level, off-farm income, veterinary services, credits, beef cattle fattening, and household size, all of which minimize profit inefficiency, thereby increasing profit efficiency. Distance to market is positively connected to profit inefficiency among Tanzanian traditional beef cattle farmers, implying that it increases profit inefficiency, thereby reducing profit efficiency. The variables involved are described below.

Access to information about the market is an important variable to figure out how it affects profit efficiency. Access to market information was positively associated with profit efficiency at the 5% level. This implies that the program implemented by the Ministry of Livestock and Fisheries (MLF) and the Ministry of Trade (MT), namely, the livestock information network knowledge system (LINKS), which gathers, analyzes, and disseminates livestock market information, has been fruitful to traditional beef cattle farmers in terms of profit efficiency maximization. Access to market information is vital to the growth of traditional beef cattle farmers because it generates the required demand (profitable market access) and provides remunerative pricing, hence enhancing beef cattle sales and profit efficiency [73]. As not all farmers took part in the program, it is difficult to draw firm conclusions about its effects on profit efficiency; as a result, the Heckman treatment effect model was applied as a robustness check, and its results are provided in Section 3.3.4.

At the 5% significance level, the educational coefficient is positively associated with profit efficiency. This supports the well-established fact that well-educated farmers save money (cost-effectiveness) and has important implications for the social and cultural capital benefits that literacy may help to organize. Beef cattle productivity and profitability rely heavily on the capacity to apply information and use ideas, both of which are greatly aided by education [74]. The factor also serves as a predictor of the adoption of innovations and new technology necessary to increase beef cattle productivity [61].

At the 10% level of significance, a positive relationship was identified between household size and the profit efficiency of beef cattle farming. Big families have the opportunity to involve considerably more household labor in production and marketing activities, thereby increasing profit efficiency by reducing hired labor costs for herding. Farmers with the manpower to care for beef cattle may maintain a larger herd, which improves their chances of making profits [61]. As a result, increasing household size reduces farmer profit inefficiencies, thereby increasing profit efficiency. This finding is consistent with earlier findings by Kolawole [75] and Saysay [76].

Farming experience significantly improved profit efficiency at the 5% level. This suggests that farmers with more experience in beef cattle production made more money because they capitalized on market shifts in the beef cattle business. That is to say, farmers who have been producing beef cattle for years often earn greater profits (profit efficiency) per beef cattle. This finding is consistent with earlier findings by

Table 5. Distribution of profit efficiency scores among traditional beef cattle farmers

Profit Efficiency Level	Frequency	Percentage (%)
0.05 - 0.25	12	3.05
0.26 – 0.50	86	21.88
0.51 – 0.60	191	48.60
0.61 – 0.70	60	15.27
0.71 – 0.80	26	6.62
0.81 – 0.90	13	3.31
0.91 – 1.00	5	1.27
Total	393	100
Mean	0.49	
Maximum	0.81	
Minimum	0.16	

Source: Author's field survey data

Table 6. Maximum likelihood estimations for profit inefficiency model parameters

Inefficiency effect model variable	Coefficient	Std. Error.	t-stat.
Constant	4.384	1.027	4.218**
Age of a farmer	0.049	0.156	0.312
Educational level	-0.325	0.087	-2.723**
Household size	-0.062	0.051	1.322*
Farming experience	-0.342	0.178	-3.421**
Off-farm income	-0.214	0.076	-1.612**
Access to veterinary services	-0.173	0.161	-2.433**
Access to farm credits	-0.085	0.110	-2.181**
Access to market information	-0.301	0.201	-2.160**
Cooperative membership	-0.231	0.167	-3.310
Beef cattle fattening (value addition)	-0.341	0.168	-2.257**
Distance to market	0.124	0.021	1.034**

Source: Author's field survey data; ***, **, * *denote statistical significance at 1%, 5%, and 10%, respectively*

Afolabi & Olude [77] and Sadiq & Singh [78]. The farming experience shows the success of social media platforms and strengthened links in the pursuit of prospectively profitable customers [79]. In addition, farming experience gives knowledge and production methods that are regarded as beneficial for production and selling at a higher price for maximum profit [80].

Also, at the 5% level of significance, access to farm credits improved the profit efficiency of beef cattle farming. This positive pattern may be seen as a correlation between a farmer's access to farm credits and the profit efficiency of beef cattle farming. Credit to farms is a measure of the financial resources accessible to commercial farming for maximizing profit efficiency. Credit is a stimulus for the adoption of advanced technologies, such as enhanced beef cattle breeding, beef cattle fattening, etc., which reduce profit inefficiency. Credit is a significant factor that can improve profit efficiency [81]. Thus, credit constraints increase the inefficiency of farmers by restricting the use of technology and the acquisition of critical information for boosting profitability.

The exposure to the veterinary services coefficient is significant and positive at the 5% level of profit efficiency. This indicates that beef cattle farmers with more access to veterinary services and education were more profitable and efficient in their beef cattle operations. This finding is consistent with that of Bravo-Ureta & Pinheiro [52], who indicated that engagement through veterinarian visits provides farmers with an opportunity to acquire and adopt new technologies and resources, hence maximizing profit efficiency.

Likewise, at a 5% significance level, the coefficient for off-farm income demonstrated a positive relationship with profit efficiency. This suggests that farmers with a huge non-farm income are more efficient, all else being equal. This finding validates the significance of off-farm income for traditional beef cattle farmers, who often have fewer family resources to draw on in mitigating transactions and other expenses associated with running a farm. It is also essential to mention that money made outside the farm may be reinvested back into farming operations as either fixed or working capital, which can improve productivity and profitability both immediately and over the long run. The results are consistent with those of Bahta & Baker [47] and Otieno [64], who both found that beef cattle producers' off-farm income was significantly correlated with their profit efficiency.

The coefficient for beef cattle fattening (value addition) had a positive influence on beef cattle profit efficiency and was statistically significant at the 5% level. The practice of fattening beef cattle adds value, which in turn raises productivity and market value, thereby maximizing profit efficiency. Ideally, the use of contemporary technology leads to an improvement in farm profits efficiency via a boost in high-value marketable products, which has a favorable impact on job prospects and wealth.

Furthermore, the distance to the most frequented market has a negative and statistically significant relationship with profit efficiency at the 5% level. Due to the structure of the rural transport system, marketing beef cattle to distant markets incurs additional travel expenses, thereby lowering profit efficiency. Additionally, the age of a farmer was found to be negatively associated with profit efficiency, but the relationship was not statistically significant. Cooperative membership was found to be positively associated with beef cattle efficiency, but the relationship was not statistically significant.

Generally, the factors in the inefficiency model are essential because of their direct relationship with improved profit efficiency levels among beef cattle farmers. As a result, government and development partner actions aimed at alleviating rural poverty and sustaining beef cattle production should be prioritized.

3.2.4 Second stage heckman treatment effect model for robustness test

To check for robustness. The OLS model is utilized as a robustness test on the influence of the chosen factor (market information access) on the profit efficiency scores of farmers, which were previously, derived using the inefficiency model in Table 4. The Inverse Mills Ratio (IMR) is 0.79, as shown in Table 7. The utilization of Heckman's model to address the issue of bias in the selection of beef cattle farmers is supported by the positive and statistically significant IMR at the 5% level. Access to market information is positively related to profit efficiency among farmers, with a projected coefficient of 0.432 and a 5% significance level. It confirms the inefficiency model's conclusions and shows that market information accessible through the government program boosts profit efficiency by

Table 7. Second stage heckman treatment effects model estimate (Profit efficiency as a dependent variable)

Variable	Coefficient	Std. Error.	t-stat.
Constant	0.617	0.032	15.23***
Age of a farmer	-0.027	0.045	-1.42
Educational level	0.271	0.036	6.84**
Household size	0.031	0.021	1.31
Farming experience	0.321	0.124	20.78**
Off-farm income	0.233	0.061	1.36**
Access to veterinary services	0.062	0.040	2.11
Access to farm credits	0.137	0.021	3.15**
Access to market information	0.432	0.102	2.27**
Cooperative membership	0.122	0.106	2.57
Beef cattle fattening (value addition)	0.322	0.037	3.16**
Distance to market	-0.224	0.032	-5.04*
Goodness-of-Fit Test			
Wald chi^2	43.87**		
Lambda (IMR)	0.736**		
Sigma	0.585		
Rho	0.791		
Observations	393		

*Source: Author's field survey data; ***, **, * denote statistical significance at 1%, 5%, and 10%, respectively*

about 42.3%. Moreover, other factors, such as educational level, farming experience, off-farm income, access to credit, and beef cattle fattening practice (value addition), were found to positively impact profit efficiency in a robust test. An increase in profit efficiency due to education averaged 27.1% at the 5% significance level among farmers. The farming experience was shown to be significant at the 5% level, increasing profit efficiency by 32.1%. Similarly, at the 5% significant level, off-farm income, access to finance, and beef cattle fattening (value addition) positively increased profit efficiency by 23.3%, 13.7%, and 32.2%, respectively. Besides, after a robustness test, household size, age of the farmer, cooperative membership, and access to veterinary services were revealed to be positive but not statistically significant factors in increasing profit efficiency. Furthermore, at a significance level of 10%, the distance to the market was shown to lower profit efficiency by 0.224%. Traditional beef cattle farmers had little access to veterinary services and cooperative membership, thus their effect on profit efficiency was negligible.

4. CONCLUSION

This study sought to gain empirical evidence on the level of profit efficiency (PE) among traditional beef cattle farmers in Tanzania. Notably, to determine if farmers are profitable along the profit frontier (efficient) by generating the stochastic frontier profit function to capture the profit inefficiency effects to identify the areas of intervention for further optimizing the commercialization of the industry to ensure better household income, food security, and the country's economic growth, thereby alleviating poverty among farmers. Specifically, this study was designed to: (i) assess the socioeconomic characteristics of traditional beef cattle farmers; and (ii) measure profit efficiency and its determinants in traditional beef cattle farming.

The socioeconomic results showed that farmers had low levels of education, limited access to credit and veterinary services, and didn't take part in farmer cooperatives very much (limited involvement in farmer cooperatives). Such limitations tend to lower profit efficiency. However, the findings also revealed that farmers had moderate access to market information, an active-age labor force, a larger labor force, sufficient farming experience, sufficient beef cattle herd sizes, sufficient grazing land, and sufficient off-farm income, all of which are essential resources in beef cattle production for maximization of profit efficiency. Moreover, the findings revealed sufficient characteristics of beef cattle flocks, such as cows, bulls, and heifers. These flock characteristics are concerned with beef cattle herd dynamics, which are marked by higher beef cattle productivity, hence boosting profit efficiency. The findings suggest that people with high levels of education should be encouraged to invest in beef cattle production to boost beef cattle production and marketing for maximization of profit efficiency. Also, farmers who already raise beef cattle should get specialized training and education to help the traditional beef cattle sector grow. The findings further suggest that incentives should be set forth to attract beef cattle farmers to join cooperatives. This is because cooperatives help farmers mobilize resources, share market information, improve their bargaining power, promote their services, and reduce costs through economies of scale, thereby increasing for maximization of profit efficiency. In the same way, traditional beef cattle farmers should have better and more secure access to farm loans. Farm credit is important for making investments in beef cattle production and marketing. This increases the productivity of beef cattle, which increases for maximization of profit efficiency, which helps reduce poverty.

Moreover, profit efficiency (PE) analysis found that traditional beef cattle farmers are not profit efficient, with an average profit efficiency of 49%. This means that traditional beef cattle farmers lose an average of 51% of their profits owing to technical and allocative inefficiency, thereby accelerating poverty rates. It further indicates that farmers are making a profit at a mean level of 51% below the frontier profit. Besides, at a 5% significance level ($P < 0.05$), the cost of medications and supplements, cost of labor for herding, cost of spraying/dipping parasites, marketing and transportation costs, and keeping local breed beef cattle were statistically significant and negatively contributed to the profit efficiency of traditional beef cattle farmers. While grazing land owned and beef cattle herd size were statistically significant and positively contributed to the profit efficiency. As a result, if variable costs of production are controlled to the maximum extent possible, an improvement in profit efficiency will result in a large gain. Furthermore, the estimated profit inefficiency model variables and second stage Heckman treatment effect model for robustness test, show that at a 5% significance level ($P < 0.05$), access to market information, educational level, farming experience, off-farm income, access to credit, and beef cattle fattening (value addition) all have a significant negative influence on profit inefficiency, thereby enhancing profit efficiency. Whilst the distance to the market increased the level of profit inefficiency, thereby decreasing profit efficiency. This indicates that there is still a substantial chance for farmers to increase profit efficiency in beef cattle farming, hence reducing poverty among farmers if the variables influencing profit inefficiency are effectively addressed. This also shows that traditional beef cattle farmers still have a lot of room to improve the economic sustainability of beef cattle farming. Failure to improve profit efficiency in beef cattle production is what contributes to an unsustainable economy among traditional beef cattle farmers. Thus, beef cattle farming should be more commercialized to sustain the economies of traditional beef cattle farmers and the nation at large, thereby reducing poverty among farmers. Commercial-oriented farming requires the development of their way of thinking, from production for family needs and the local market to profit orientation.

In general, the results have shown that, despite efforts by the government, the traditional beef cattle industry is not commercialized enough to reduce poverty and low GDP contribution. This has been affected by a variety of issues that impact profit maximization (profit efficiency). Hence, the government should focus on addressing the factors that improve profit maximization (profit efficiency) for farmers, leading to increased income and food security. The results of this study agree with the UN's 2030 Agenda for Sustainable Development, which seeks to double farmers' incomes by 2030 to reduce poverty [82]. Recommendations for future research is that researchers should study critically the consolidated impacts of profit efficiency on the well-being and food security of traditional beef cattle farmers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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