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Drivers of smallholders' cattle commercialisation in rural Tanzania and implications for leveraging opportunities in the beef sector

Njile Isack Shashi[1,2*], Hillary Kiplangat Bett[1] and Mary Mathenge[1]

*Correspondence:
Njile Isack Shashi
njile.shashi@nm-aist.ac.tz
[1]Department of Agricultural Economics & Agribusiness Management, Egerton University, P. O. Box 536,
Njoro, Nakuru County 20115, Kenya
[2]Nelson Mandela African Institution of Science and Technology (NM-AIST), P.O Box 447, Arusha, Tanzania

Abstract
The linkage between agricultural commercialisation and improvements in household welfare has received a significant attention in literature. Despite the growing interest, livestock commercialisation particularly beef cattle which is among the principal sources of meat protein in Tanzania is inadequately elucidated. Subsequently, there is a paucity of empirical evidence on the drivers of commercialisation and policy implications to guide beef cattle sector in Tanzania. This study was delved to fill this research gap by determining the factors influencing beef cattle commercialisation among smallholder farmers. Cross-sectional survey was used whereby a multistage sampling method was used to obtain 400 randomly selected farmers in Arusha region. A semi-structured questionnaire was used to solicit information from the smallholder farmers between September and October 2024. Fractional probit model was used to determine the factors influencing beef cattle commercialisation among the farmers. The results showed that, age of the farmer and access to extension services are important determinants of beef commercialisation ($\alpha = 0.01$). Moreover, the results revealed that, farmers' sex, membership in farmer's group, distance to nearest main road, tropical livestock unit (TLU), earning of off farm income and shock occurrence statistically significant influenced commercialisation ($\alpha = 0.01$, $\alpha = 0.05$ and $\alpha = 0.1$). This study highlights the role of agricultural extension services to smallholder farmers' commercialisation decision. It therefore recommends a provision of extension services to reach the remotely cattle farmers to boost commercialisation. Similarly, the study asserts the need for interventions to ease the enabling infrastructure such as rural roads and gender sensitive programs for cattle producers to enhance commercialisation for harnessing emerging opportunities in beef sector.

Keywords Beef cattle, Commercialisation, Fractional probit, Offtake rates, Smallholder farmers

1 Introduction

Globally, the livestock sector is a key component of the agri-food systems, contributing to food and dietary nourishment and farmers' income. According to Food and Agriculture Organization [1], the share of livestock to the agricultural output is about 40% in developed economies, and 30% in less developed economies with significant contribution in incomes. In Africa, the livestock sector is among the most supportive agricultural enterprises for the rural and peri-urban households. Accordingly, the livestock sector contributes at least 30% to 80% to agricultural gross domestic product in African countries [2].

Specifically, in Ethiopia livestock farming contributes to 45% of the agricultural GDP while in Botswana it contributes to 80% of agricultural GDP [3, 4]. Additionally, in Uganda livestock contributes to 4.3 per cent of the GDP [5] and 3.6 per cent of the GDP in Kenya [6]. In Tanzania, livestock farming supports over one million pastoral and agro-pastoral households, with cattle production organized in agro-pastoralism, pastoralism, and commercial ranching systems.

As of 2022, Tanzania's cattle herd reached 36.6 million making the country second after Ethiopia [7]. Furthermore, according to National Bureau of Statistics of Tanzania [8], about 90% of cattle kept are indigenous cattle (Short Horn Zebu) and are under smallholder farmers. Cattle contribute to about 64% of the total meat produced and consumed in Tanzania, followed by sheep and goats [7]. In that light, smallholder farmers make a significant source of beef supply from the cattle for consumption both in the domestic and export markets.

Several studies have examined agricultural commercialisation among smallholder farmers as providers of agri-food products in African countries. Seminal contributions for instance by [9, 10] pinpointed the factors determining crop commercialisation in Sub-Saharan Africa. Moreover [11, 12] described the nexuses between crop commercialisation and welfare effects among farmers. Nevertheless, little attention has been given on understanding commercialisation by beef farmers, without exclusion to Tanzania.

Smallholder beef cattle commercialisation holds significant sway on developmental outcomes such as improved incomes, dietary intakes and rural growth. Moreover, in the light of the growing demand for animal sourced foods (ASFs), cattle commercialization would play a critical role in addressing demand for beef. Kibona et al. [13] highlights that, in Tanzania the current meat demand surpasses supply due to low commercialisation among smallholder cattle farmers. Milford et al. [14] argued that, the continuous dynamics in economic and socio-economic factors stimulate meat consumption and thereby represent lucrative opportunity in the beef sector.

In that regard, understanding the determinants of cattle commercialisation is imperative to guide policy makers in designing measures to harness the emerging market opportunities driven by livestock revolution. The World Bank [15] avowed that, livestock sales is among important source of incomes in smallholder farmers. Subsequently, there is growing literature on market participation, cattle value addition such as traditional fattening and profitability analysis in Tanzania (for instance by [16–18]). Nevertheless, such literature did not consider the drivers of cattle commercialisation among the smallholder farmers.

Most studies have focused on crop commercialisation with scanty research on livestock, particularly beef cattle commercialisation among smallholder farmers in

Tanzania. Few studies, for instance, the study by [19] examined the lucrativeness and viability of smallholder pastoralist cattle enterprises. Furthermore [17], assessed the market participation among smallholder farmers in the agro-climatic areas of Tanzania. Other authors for instance [20–22] estimated the profitability of indigenous beef cattle feedlots in Tanzania.

The existing studies left out beef cattle commercialisation among smallholder farmers and implications on harnessing the growing market opportunities such as the projected doubling demand for ASFs. Moreover, studies by [17, 23] examined market participation in beef chains among farmers. Previous studies employed linear regression models which may predict probabilities outside (0, 1) interval [24] thereby limiting their applicability in modeling commercialisation indices.

The contribution of this study is two-fold. First this study utilizes the fractional probit model to overcome the limitations in linear probability and two step models, and provide robust estimates of the determinants of beef cattle commercialisation. Secondly, this study adds to the body of literature on drivers of cattle (beef) commercialiastion among smallholder farmers in rural setting and suggest relevant policy implications to respond to the emerging market opportunities in beef sector.

2 Materials and methods

2.1 Study area

This study was done in the rural areas of the Arusha region located in northern Tanzania, an area known for its significant concentration of indigenous cattle [8, 25]. The region, is dominated by smallholder pastoral and agro-pastoral farmers, and has witnessed growth in livestock auction markets. Two districts, Monduli and Longido districts were purposively selected due to their large numbers of smallholder beef cattle farmers and growing market participation attributed to government interventions [26, 27]. These districts provide a representative context to investigate beef cattle commercialisation among smallholders. In this study, smallholder cattle farmers refers to family based subsistence farmers (livestock keepers) and resource poor characterized by low-input and low technology systems under area less than 5 acres.

2.2 Research design, sampling procedure and sample size

A cross-sectional survey design was adopted for this study. Primary data on socio-economic characteristics and commercialisation practices were collected from the selected respondents in study areas at one point in time. Multistage sampling was used to obtain the required sample in the study areas. This technique fits well when the sample is to be drawn from a big geographic area such as a country [28]. First, Arusha region was purposively selected for its prominence in indigenous beef production in Tanzania [8]. In the second stage, two districts - Longido and Monduli were purposively chosen based on high concentration of smallholder cattle farmers. In the last stage, a simple random sampling was used to select smallholder cattle farmers for data collection from the sampling frame obtained from the ward extension officer.

The sample size in the study was determined by the Cochran formula as follows in Eq. (1).

$$\mathrm{n} = \frac{\mathrm{z}^2\mathrm{pq}}{(\mathrm{e}^2)} \tag{1}$$

In Eq. (1) above, $n =$ sample size; $z =$is a standard value at a given confidence interval ($\propto = 0.05$), $p =$ estimated proportion (0.5) to ensure maximum possible variance, $q = 1 - p$ and $e =$ sampling error which (5%). The resulting sample size is shown in Eq. (2).

$$n = \frac{(1.96)^2\ (0.5)\,(0.5)}{(0.05)^2}\ 384 \tag{2}$$

However to take into account for possible missing information and non-response, the study collected data from a total of 400 (174 in Londido district and 226 in Monduli district) smallholder beef cattle farmers from the study areas.

2.3 Data sources and analysis

Primary data was collected from smallholder farmers between September 2024 and October 2024 using a semi-structured questionnaire. Data collection entailed soliciting information from the beef farmers on the socio-economic, institutional support variables and commercialisation practices. Data analysis involved estimation of both descriptive statistics and econometric modeling, with both pre-estimation and post-estimation tests to ensure model fitness.

2.4 Analytical framework

Jaleta et al. [29] posited that, livestock commercialisation such as sales of live animals can be measured using market off-take rates. In that light, this study used cattle market offtake rate as a proxy for beef cattle commercialisation among smallholder farmers. Market off-take encompass sales of cattle to the market for slaughters, ceremonial transactions or other uses by the buyers [30]– [31]. The measure reflects the sales of the beef cattle by smallholder farmers in a specific period of time. Thus, beef cattle commercialisation was computed as number of cattle sold dividing the number of opening and closing stock (total herd size) in a year. The measure has been used by several studies such as by [32]– [33]. Market off-take rate represents beef cattle sold as a fraction of the average stock as expressed in Eq. (3)

$$market\ of ftake\ rate = \frac{Sales - purchases}{0.5(Opening\ stock + ending\ stock)} \tag{3}$$

Two step procedures particularly Heckman sample selection and Craig double hurdle models are among the commonly used econometric models in agricultural commercialisation. Authors for example [34–36], modelled commercialisation by using a Heckman model which involves the unobservable selection decision and intensity of commercialisation. However, Heckman [37] posited that, the application and fitness of the Heckman sample selection model is appropriate in truncation scenarios in which unobserved values are labelled as zeros.

Similarly, the studies by [38–42] modelled agricultural commercialisation by using the Craig double hurdle model. Arguably, two-steps process (decision to commercialise and the extent of commercialisation) are inseparable in nature due to unmeasured factors

influencing the selection and the intensity decision [43]. Equally, Wulff [44] asserted that, the process of the selection and intensity decision in commercialisation is non-random. Subsequently, the non-randomness result into correlation between the errors of the selection and intensity equations, leading to the inaccurate estimates of the model's parameter on the variables influencing the intensity [43, 45].

Thus, the use of two step procedures is inappropriate particularly when the dependent variable is a fraction or percentage [46–48]. In realisation of the nature of the dependent variable (a proportion or fraction) of sales, this study used the fractional regression model (FRM) to determine the factors influencing beef cattle commercialisation. FRM allows value that are equal or greater than zero and less than or equal to 1 by provide the conditional expectation of the outcome variable based on binary (logistic or probit) function which generates consistent parameter estimates [43]– [44]. Accordingly, Wulff [44] argued that the FRM predicts response values within the interval limits allowing zeros and ones from below and above, taking into account the non-linearity nature of the data, thereby yielding efficient estimates. The conditional mean of the FRM outcome is shown as in Eq. (4)

$$E\left(y_j|x_j\right) = G\left(x_j\beta\right),\ 0 \leq\ y \leq\ 1 \tag{4}$$

In equation (ii), $y_j = 0 \leq\ y \leq\ 1$ is the dependent variable (market offtake rate), and (x_j) denotes independent variables for j^{th} observation. Accordingly, G(.) is a known function such as logistic function or standard normal cumulative density function satisfying the $0 < G(z) < 1$ [46]– [47]. $E\left(y_j|x_j\right)$ is population conditional mean of the proportion of cattle commercialized and β is vector of parameters to be estimated in the model. Fitting FRM is by the quasi-maximum likelihood (QML) technique based on a Bernoulli log-likelihood is used [46]. The log-likelihood (Bernoulli) function is hypothesized as in (5)

$$lnL = \sum\nolimits_{j=1}^{N} w_j y_j ln\left\{G\left(x_j'\beta\right)\right\} + w\left(1-y_j\right) ln\left\{1 - G\left(x_j'\beta\right)\right\} \tag{5}$$

In (iii), N is the sample size, y_j is the dependent variable, w_j represents the optional weights, x_j are the covariates for individual j and lnL is maximized using Bernoulli method. $G\left(x_j'\beta\right)$ is the functional form which can be estimated by either probit model $\left(\Phi\ \left(x_j'\beta\right)\right)$ or logit model $\left(\frac{\exp\left(x_j'\beta\right)}{1+\exp\left(x_j'\beta\right)}\right)$. In this study, probit model was used to fit the factors determining commercialisation (measured as market offtake rate) among smallholder farmers as follows.

$$E\left(market\ offtake|x\right) = \Phi\ \left(\beta_0 + \beta_1 x_1 + \ldots\ \beta_n x_n + \mu\right) \tag{6}$$

Where market offtake is the dependent variable, $(x_1 \ldots\ .x_n)$ denotes independent variables for j^{th} observation, $B_0 \ldots\ .B_n)$ represent unknown parameters to be estimated and μ represents error term. Descriptions and measurements of the variables that were used to fit the FRM are shown in Table 1.

Table 1 Fractional regression model variables and their priori expectation

Variables	Variable description and measurements	E (-/+)
Dependent		
Market offtake rate	Sales-purchases/0.5(opening stock-ending stock)	
Regressors		
Age	Age of the farmer in years (Continuous)	+/-
Sex	Sex of the household head (Dummy; 1 = Female, 0 = Male)	+/-
Household size	Number of household members (Discrete)	+/-
Education	No. of years of schooling of the household head (Continuous)	+/-
Extension	Accessed extension service in the last 12 months (1 = Yes, 0 = No)	+/-
Membership	Membership in farmers group (Dummy; 1 = Yes, 0 = No)	+/-
Credit Access	Access to credit by the farmer (Dummy; 1 = Yes, 0 = No)	+/-
TLU	Livestock owned in TLU (continuous)	+/-
Trust	General trust on traders (Dummy; 1 = Yes, 0 = No)	+/-
Distance	Distance to the nearest market in kilometers (Continuous)	+/-
Off-farm	Earning of off-farm income (Dummy; 1 = Yes, 0 = No)	+/-
Shocks	Experienced shocks such as droughts and livestock deaths in the last 12 months (Dummy; 1 = Yes, 0 = No)	+/-
Phone ownership	Own mobile phone (Dummy; 1 = Yes, 0–=No)	+/-

Table 2 Summary statistics of the sampled households across the districts

Continuous variables/district	Monduli district (*n* = 226)		Longido district (*n* = 174)		Test statistic
	Mean	SD	Mean	SD	t-test
Age	44.14	13.63	43.35	11.18	−0.62
Years of schooling	4.83	4.30	3.66	3.84	−2.83**
Experience (years)	21.30	13.42	25.23	12.24	3.02***
Household size	8.42	4.98	9.07	5.13	1.27
TLU Owned	16.13	27.63	18.02	21.14	0.75
Dependency ratio	1.18	1.34	0.99	0.89	−1.69*
Distance to nearest road (km)	6.31	6.38	6.59	5.42	0.46
Distance to nearest livestock market (km)	3.77	4.19	4.42	4.03	1.54

*, ** and *** are level of significant at 10%, 5% and 1% respectively. Values in parentheses are percentages. Sd refers to the standard deviation

3 Results and discussion

3.1 Descriptive statistics of the sampled households

Table 2 presents comparative statistics of the independent variables used in the study. The comparison between Monduli and Longido districts was made using t-tests for continuous variables and chi-square tests for categorical variables. Significant differences were observed in years of schooling, experience in cattle production, and dependency ratios. Furthermore, significant differences were found for access to market information, non-farm income, and extension services among households across the two districts. The detailed results with mean and standard deviation (SD) for the variables are presented in a Table 2.

3.2 Description of the dependent variable

The dependent variable, market offtake rate, was calculated as the proportion of cattle sold relative to herd size per household annually. The observed market offtake ranged from 0% to 100%, with a mean of 13.1%, indicating generally low levels of

Table 3 Coefficients and marginal effects of the factors influencing commercialisation

Variables	Robust		Delta method	
Market offtake	**Coef.**	**SE**	**dy/dx**	**SE**
Age	0.008***	0.003	0.001***	0.001
Female headed household	−0.381***	0.151	−0.072***	0.028
Schooling (years)	0.003	0.011	0.001	0.002
Household size	0.003	0.009	0.001	0.002
Group membership	−0.238*	0.135	−0.045*	0.025
Received extension service	0.249***	0.088	0.047***	0.016
Received credit	0.0466	0.135	0.009	0.025
Distance to nearest main road (km)	−0.037***	0.011	−0.006***	0.002
Distance to nearest livestock market (km)	0.007	0.007	−0.007	0.002
TLU	−0.005**	0.002	−0.001**	0.000
Trust livestock traders	−0.076	0.120	−0.014	0.023
Accessed market information	−0.090	0.081	−0.017	0.015
Earned non-farm income	−0.700**	0.284	−0.132**	0.054
Experienced shock	−0.259**	0.105	−0.049**	0.020
_cons	−0.769**	0.311		
Wald chi2(14) = 66.61of				
Prob > chi2 = 0.0000				
Observations = 400				

*, ** and *** are level of significant at 10%, 5% and 1% respectively. SE represents standard errors

commercialisation among smallholder beef cattle farmers. These findings align with previous studies in Sub-Saharan Africa [32, 49].

3.3 Determinants of commercialisation among smallholder beef cattle farmers

Table 3 presents the coefficients and the marginal effects of the factors influencing commercialisation from the fractional probit regression model. The Wald chi2 (14) = 66.61 and the prob > chi2 = 0000. Moreover, the Log pseudo likelihood was − 137.612 with the pseudo R^2 value of 0.052. The results reveal that, the model specification fits well the data in this study. The regression coefficients and the average marginal effects in the Table 3 evinced that, various household's socio-economic, institutional and external factors influence the outcome. Some of the variables that were statistically significant were age, sex, TLU, access to extension services, distance to the main road, non-farm income, group membership and shock occurrence. Notably, periodic shocks posited mixed influence on the commercialisation decision among the smallholder beef cattle farmers in the study areas.

Table 3 shows that, age has a positive and statistically significant ($p < 0.01$), implying that an increment in age is associated with increased commercialisation among smallholder farmers. Specifically, the average marginal effects results imply that, an increment of one year in the age of a household will increase commercialisation decision by 0.1%. Meaning that, as smallholder cattle farmers get old, their participation in markets increases. This could be attributed by the cumulative experience in cattle production and networking with livestock traders among aged households. Studies by [50, 51] confirmed a positive and statistically significant relationship between household age and commercialisation. Similar findings were obtained by numerous studies such as [52].

Furthermore, access to extension services was found to positive and statistically significant ($p < 0.01$). This attests that smallholder farmers who had accessed advisory services such as with respect to animal health, marketing and market information, fattening and

better feeding practices had commercialised a proportion of their beef cattle. Particularly, access to extension services among smallholder farmers increased commercialisation by 4.7%. The findings corroborate with [53], asserting a positive and significant relationship between access to extension services and commercialisation among smallholder farmers. Additionally, seminal contributions by [34, 54] attest that there is statistical and significant relationship between access to agricultural advisory services and commercialisation in smallholding agriculture.

Sex of the household head was found to be negative and statistically significant in influencing beef cattle commercialisation ($p < 0.01$). The results show that, a female-heading household reduced cattle commercialisation by 7.2%. This is attributed by the fact that, in many areas of the developing countries including Tanzania, women own fewer productive resources such as cattle compared to men. Similarly, studies by [55–57] argued that, women in developing countries own lesser livestock compared to men, and in most cases, women own small ruminants (such as goats) and poultry. Moreover, studies by [9, 58] revealed that women own cattle for milk production as the end product, not selling of the cattle. Equally [59], found that women participate in milking, processing and selling livestock products.

Expectedly, distance to nearest main road was found to negative and statistically significant in influencing beef cattle commercialisation ($p < 0.01$). From the Table 3, an increase in the distance to the nearest road by one kilometre (1 km) will decrease commercialisation among smallholder cattle farmers by 0.6%. This suggests that, smallholder cattle farmers who live away from the main road are less likely to participate in selling their cattle when compared to smallholder farmers who are nearer to the main road. The distance to the main road roads may have implication on the transport costs and therefore disfavour commercialisation among the smallholder farmers [54, 60]. This indicates that, distance to the main road preclude smallholder farmers from utilizing market opportunities and henceforth reduces commercialisation. The findings are similar to results from studies by [50, 52] who found a similar negative relationship between agricultural commercialisation decision and distance to the necessary infrastructure such as all-weather roads.

Surprisingly, membership in farmers group was found to be negative and statistically significant ($p < 0.1$) in influencing cattle commercialisation among smallholder farmers. This suggests that, being a member in farmers' group reduces commercialisation by 4.4%. The possible reasons could be due to inadequate linkage between members in the farmer's group and the supporting institutions and service providers in the study areas. Similarly [61], argued that group characteristics such as in terms of size, asset endowments, poverty level, trust and sex composition among group members may influence marketing decision differently. The results are comparable to findings by [17] who found a negative and statistically significant relationship between market participation of beef cattle farmers and group membership in Simanjiro district, Tanzania. Conversely [62], found a positive and statistically significant relationship between being a member in farmer's group and commercialisation. The mixed effects of the relationship between farmers group and commercialisation can be due to inadequate understanding of the roles of farmer's group in enhancing market access and networking with market participants such as buyers.

Occurrence of negative shocks in the last calendar year (12 months) was found to be negative and statistically significant ($p < 0.1$). This means that, being affected by shocks particularly drought among smallholder farmers resulted to a decrease in beef cattle commercialisation by 3.6%. This is ascribed by the fact that, occurrence of shocks associate with drop of livestock productivity, conflicts and loss of cattle (reduction in livestock holdings) due to deaths which lowers livestock herd size [63, 64]. Moreover, occurrence of negative shocks significantly associates with lack of adequate pasture, migration and decline in productivity, and subsequently reduce marketable livestock [65, 66]. The results are similar to observation by [67] who found a negative and statistically significant relationship between weather shocks and market participation among smallholder farmers in Malawi.

Likewise, results indicated that earning non-farm income significantly influenced cattle commercialisation among smallholder farmers ($p < 0.5$). Earning non-farm income resulted into a decline in beef cattle commercialisation by 13.2%. This negative relationship may suggest that, having alternative sources of income among smallholder farmers provide the households with additional means of smoothing consumption of required needs such as food and nutrition, health, housing and sanitation [54]. Consonantly, non-farm income can be spent on purchasing other household needs such as schooling and productive and non-productive resources for the household [68]. In that regard, non-farm income may lower the need of beef cattle commercialisation among smallholder farmers. A similar outcome was found by [69] confirming that, having alternative and multiple sources of income may lower agricultural commercialisation.

Additionally, as shown in Table 3, TLU owned was negative and statistically significant in influencing smallholder' commercialisation ($p < 0.5$). The results evinced that; a unit increase in TLU owned by smallholder farmer will lower cattle commercialisation by 0.1%. The negative relationship between the TLU and commercialisation could be ascribed by the diversification of livestock holdings such that, smallholder farmers will be able to sell other species for instance goats and sheep, instead of relying on cattle sales for income generation. Mirie and Zemedu [70] and Mdoe et al. [71] found a negative and statistically insignificant relation between market participation and commercialisation among smallholder farmers in Ethiopia and Tanzania respectively.

4 Conclusion and policy recommendations

Agricultural commercialisation plays a vital role in enhancing household welfare, increasing income diversification, and driving rural economic growth in developing countries, including Tanzania. This study examined the drivers of cattle commercialisation among smallholder farmers sampled in rural areas of Arusha region, Tanzania. The results indicated a mean market offtake rate of 13.1%, implying that smallholder beef cattle farmers sell a relatively small proportion of their herd to the market annually. Some of the reasons for keeping and selling the fraction of their livestock holdings were found to be income generation motives to fulfil personal and family needs such as educational needs, food and nutrition, and purchases of assets. The low commercialisation (market off-take rates) among smallholder farmers indicates a dubious prospect of equilibrating the supply and the growing demand for ASF where beef meat contribute immensely.

The fractional probit results evinced that households socio-economic and institutional aspects are among the important determinants of the smallholders' beef cattle commercialisation. Specifically, age of the household head, access to extension services, and TLU positively and significantly influenced commercialisation. In contrast, distance to main roads, female-headed households, shock occurrence, off-farm income, and group membership negatively and significantly affected market participation.

The study's findings attest that, access to extension service is pivotal for smallholder participation in commercialisation activities. Extension services provided to smallholder farmers often include intensification strategies such as fattening and finishing practices, which improve live weight gain and enable farmers to obtain better market prices. In that light, access to extension services empirically attests the policy implication for the government, non-government organisations and private sector to ensure wider provision of agricultural advisory services to smallholder beef cattle farmers.

The negative association between group membership and commercialisation suggests the need to strengthen farmer groups by improving their governance, leadership capacity, market linkages, and access to accurate market information. Moreover, the groups should be oriented to improve their productivity and market participation for an enhanced utilization of emerging opportunities in the beef sector. The study recommends investment in physical infrastructure, particularly the construction and upgrading of main roads, to enhance market accessibility and reduce transaction costs for smallholder farmers. Moreover, this study recommends measures such as social safety nets and livestock insurance programmes as protective and mitigation measures to overcome such calamities and restore livestock holdings for an enhanced commercialisation among farmers.

Furthermore, government and organisations intended to enhance smallholder farmer commercialisation should invest in the utilisation of non-farm income to boost productivity by practising in high value beef breeds. In addition, gender-sensitive interventions, such as targeted asset transfer programs and access to productive resources, are essential to address structural constraints that limit women's participation in beef cattle markets. Furthermore, to leverage the existing diversified livestock holdings (TLU) owned by households, the government and development partners should promote training, improved breeding programs, and market development for multiple species to meet growing domestic and export demand.

Supplementary Information

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Supplementary Material 1.

Author contributions

Njile Shashi visualized, conceptualized, designed the methodology, data analysis and writing of the first draft paper. Mary Mathenge and Hillary Bett involved in supervision, conceptualization, writing-review and edited the paper. All authors approved submission of the manuscript prior to its submission.

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Data availability

Data used in this study analysis will be made available upon reasonable request.

Declarations

Ethics approval and consent to participate
The ethical approval for this study was granted by the Tanzania' Commission of Science and Technology (COSTECH), permit number CST00000653-2024-2024-00791. The COSTECH has its own ethics committee which approves all types of research conducted in Tanzania including those not involving human participants in accordance to the Institutional Review Board (IRB) ethics. In that regard, the approval was obtained from the COSTECH on that behalf. Participation of respondents in this study was voluntary as farmers were briefed on the purpose of the study and asked for consent prior to data collection. Informed consent was obtained from all respondents.

Consent for publication
Not applicable.

Human guidelines statement
All methods used in the study were carried out in accordance with relevant guidelines and regulations of the ethics committee listed in the ethics statement.

Competing interests
The authors declare no competing interests.

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References

1. Food and Agriculture Organization. World livestock: transforming the livestock sector through the sustainable development goals. Rome: FAO; 2018. https://doi.org/10.4060/ca1201en.
2. OECD/FAO. OECD-FAO agricultural outlook 2022–2031. Paris: OECD Publishing; 2022. https://doi.org/10.1787/f1b0b29c-en.
3. Food and Agriculture Organization. Africa Sustainable Livestock 2050--livestock sector development in Asia and sub-Saharan Africa—a comparison of livelihoods impacts. Rome: FAO; 2019.
4. Wendimu A, Tekalign W, Bojago E, Zemarku Z. Beef cattle fattening practices and marketing system in tropical highlands of Ethiopia. J Agric Food Res. 2023;14:100806. https://doi.org/10.1016/j.jafr.2023.100806.
5. Food and Agriculture Organization. The future of livestock in Uganda. Opportunities and challenges in the face of uncertainty. Rome: FAO; 2019.
6. KNBS, Kenya National Bureau of Statistics. Kenya Economic Survey 2023. 2023. https://www.knbs.or.ke/reports/2023-economic-survey/
7. MoLF, Ministry of Livestock and Fisheries. (2023). Ministry of Livestock and Fisheries Budget Speech 2023/2024.
8. NBS, National Bureau of Statistics of Tanzania. (2021). Annual agricultural sample survey report 2020/21. National Report.
9. Zantsi S, Mushunje A. The degree and determinants of smallholder commercialization in two rural provinces of South Africa. OIDA Int J Sustain Dev. 2023;16(09):43–56.
10. Chegere MJ, Kauky MS. Agriculture commercialisation, household dietary diversity and nutrition in Tanzania. Food Policy. 2022;113:102341. https://doi.org/10.1016/j.foodpol.2022.102341.
11. Mukaila R. Agricultural commercialisation among women smallholder farmers in nigeria: implication for food security. GeoJournal. 2024;89(2):42. https://doi.org/10.1007/s10708-024-11051-4.
12. Tabe Ojong MPJ, Hauser M, Mausch K. Does agricultural commercialisation increase asset and livestock accumulation on smallholder farms in ethiopia? J Dev Stud. 2022;58(3):524–44.
13. Kibona CA, Yuejie Z, Tian L. Factors that influence beef meat production in Tanzania. A Cobb-Douglas production function estimation approach. PLoS One. 2022;17(8):e0272812. https://doi.org/10.1371/journal.pone.0272812.
14. Milford AB, Mouël L, Bodirsky C, B. L., Rolinski S. Drivers of meat consumption. Appetite. 2019;141:104313. https://doi.org/10.1016/j.appet.2019.06.005.
15. World Bank. Tanzania economic update. Harnessing the Opportunity for a Climate-Smart and Competitive Livestock Sector in Tanzania; 2024.
16. Asimwe L, Kimambo A, Laswai G, Mtenga L, Weisbjerg M, Madsen J, Safari J. Meat yield and quality of Tanzania shorthorn Zebu cattle finished on molasses / maize grain with agro-processing by-products in 90 days feedlot period. J Agric Rural Dev Tropics Subtr. 2016;117(1):125–35.
17. Kibona CA, Yuejie Z. Factors that influence market participation among traditional beef cattle farmers in the Meatu district of Simiyu region, Tanzania. PLoS One. 2021;16(4):e0248576. https://doi.org/10.1371/journal.pone.0248576.
18. Kilyenyi EH, Mushi DE, Chenyambuga SW. Feed utilization and growth performance of Tanzania shorthorn Zebu fed untreated or Urea treated rice straws as hay replacement in traditional feedlot system. Anim Sci Technol. 2023;7(2):11–8.
19. Yuejie Z, Kibona CA. Examining profitability, viability and commercialization level of beef cattle production among pastoralists in the Simanjiro district of the Manyara region, Tanzania. Asian J Agric Extens Econ Sociol. 2021;39(2):141–53.
20. Kimirei S, Chenyambuga G, Mushi SW, Msalya DE, Mpenda Z. Feedlot performance and profitability of Tanzania shorthorn Zebu finished on local feed resources in Kongwa district, Tanzania. Int J Anim Sci Technol. 2022;6(4):78–85.
21. Malole JL, Kadigi RJM, Sangeda AZ. Costs and benefits of beef cattle fattening schemes in some selected areas of North West Tanzania. Iran J Appl Anim Sci. 2014;4(4):699–706.
22. Mlote SN, Mdoe NSY, Isinika AC, Mtenga LA. Profitability analysis of small-scale beef cattle fattening in the lake zone in Tanzania. J Agricultural Econ Dev. 2013;2(5):203–16.
23. Malaki CO, Damas P, Isinika AC. Factors influencing farmers' participation in the beef market chain: the case of Arusha City and Longido district, Tanzania. Tanzan J Agric Sci. 2024;40(1):201–10.
24. Chatla S, Shmueli G. Linear probability models (LPM) and big data: The good, the bad, and the ugly. Indian School of Business Research Paper Series. 2016.

25. URT, United Republic of Tanzania URT, Ministry of Finance and Planning, Tanzania National Bureau of Statistics and President's Office - Finance and Planning, Office of the Chief Government Statistician, Zanzibar. The 2022 population and housing census: Administrative units population distribution report Tanzania Mainland. 2022. pp. 263.
26. Kimaro EG, Mor SM, Toribio JAL. Climate change perception and impacts on cattle production in pastoral communities of Northern Tanzania. Pastoralism. 2018;8:1–16. https://doi.org/10.1186/s13570-018-0125-5.
27. Mfinanga FA, Msuya CP, Madaha R. Factors influencing the level of water access for livestock in semi-arid areas of Monduli district, Tanzania. Tanzan J Agric Sci. 2023;22(1):98–113.
28. Etikan I, Bala K. Sampling and sampling methods. Biom Biostat Int J. 2017;5(6):215–7. https://doi.org/10.15406/bbij.2017.05.00149.
29. Jaleta M, Gebremedhin B, Hoekstra D. Smallholder commercialization: Processes, determinants and impact. ILRI Discussion Papers, No. 18. Improving Productivity and Market Success (IPMS) of Ethiopian Farmers Project. 2009. Nairobi: International Livestock Research Institute (ILRI).
30. Scholtz MM, Bester J. Off-take and production statistics in the different South African cattle sectors: results of a structured survey. Appl Anim Husb Rural Dev. 2010;3(1):19–23.
31. Negassa A, Jabbar M. Livestock ownership, commercial off-take rates and their determinants in Ethiopia. ILRI (aka ILCA and ILRAD); 2008.
32. Gwiriri LC, Bennett J, Mapiye C, Marandure T, Burbi S. Constraints to the sustainability of a 'systematised'approach to livestock marketing amongst smallholder cattle producers in South Africa. Int J Agric Sustain. 2019;17(2):189–204.
33. Enkono SG, Kalundu SK, Thomas B. Analysis of factors influencing cattle off-take rate and marketing in Ndiyona constituency of Kavango region, Namibia. J Agric Ext Rural Dev. 2013;5(9):201–6.
34. Ayele T, Goshme D, Tamiru H, Tejada Moral M. Determinants of cereal crops commercialization among smallholder farmers in Guji Zone, Ethiopia. Cogent Food Agric. 2021;7(1):1948249. https://doi.org/10.1080/23311932.2021.
35. Belay GH, Mengstu KA, Mehammedberhan Kahsay H, Hosseininia G, Işık Özgüven A, Viira AH, Azadi H. Determinants of smallholder commercialization of livestock: a case study from Tigray. Ethiopia: Cogent Food Agric; 2021. https://doi.org/10.1080/23311932.2021.1921950.
36. Ejeta B, Masresha D. Determinants of red bean commercialization by smallholder farmers in shalla districts, oromia regional State, Ethiopia. Agric Forestry Fisheries. 2020;9(6):153–62.
37. Heckman JJ. Sample selection bias as a specification error. Econometrica. 1979;47(1):153–61.
38. Gidelew GE, Tefera TL, Aweke CS. From staple food to market-oriented crop: commercialization level of smallholder teff (*Eragrostis teff*) growers in Jamma District, Ethiopia. CABI Agriculture and Bioscience. 2022;3(1):53.
39. Zondi NTB, Ngidi MSC, Ojo TO, Hlatshwayo SI. Factors influencing the extent of the commercialization of indigenous crops among smallholder farmers in the Limpopo and Mpumalanga provinces of South Africa. Frontiers in Sustainable Food Systems. 2022;5:777790. https://doi.org/10.3389/fsufs.2021.777790.
40. Fikadu Z, Mitiku A, Megerssa GR. Commercialization of teff growers and determinants in West ethiopia: double hurdle model analysis. J Agric Environ Int Dev. 2023;117(1):141–62. https://doi.org/10.36253/jaeid-12297.
41. Taruvinga A, Singatha W, Mukarumbwa P. Factors influencing commercialisation among smallholder cabbage farmers of the Buffalo City metropolitan municipality of South Africa. J Agribusiness Rural Dev. 2021;62(4):353–62.
42. Ngango J, Musabanganji E, Maniriho A, Nkikabahizi F, Mukamuhire A. Examining the adoption of agroforestry in Southern rwanda: a double hurdle approach. For Sci Technol. 2023;19(4):260–7.
43. Wooldridge JM. Econometric analysis of cross section and panel data. 2nd ed. Cambridge: MIT press; 2010.
44. Wulff JN. Generalized two-part fractional regression with cmp. Stata J. 2019;19(2):375–89.
45. Stavrunova O, Yerokhin O. Two-part fractional regression model for the demand for risky assets. Appl Econ. 2012;44(1):21–6.
46. Papke LE, Wooldridge JM. Econometric methods for fractional response variables with an application to 401 (k) plan participation rates. J Appl Econom. 1996;11(6):619–32.
47. Ramalho EA, Ramalho JJ, Murteira JM. A generalized goodness-of-functional form test for binary and fractional regression models. Manch Sch. 2014;82(4):488–507.
48. Baum CF. Stata tip 63: modeling proportions. Stata J. 2008;8(2):299–303.
49. Kyeyamwa H, Speelman S, Van Huylenbroeck G, Opuda-Asibo J, Verbeke W. Raising offtake from cattle grazed on natural rangelands in sub-Saharan Africa: a transaction cost economics approach. Agric Econ. 2008;39(1):63–72.
50. Tafesse A, Megerssa GR, Gebeyehu B. Determinants of agricultural commercialization in Offa District, Ethiopia. Cogent Food Agric. 2020;6(1):1816253.
51. Rabbi F, Ahamad R, Ali S, Chandio AA, Ahmad W, Ilyas A, et al. Determinants of commercialization and its impact on the welfare of smallholder rice farmers by using heckman's two-stage approach. J Saudi Soc Agric Sci. 2019;18(2):224–33.
52. Abate D, Mitiku F, Negash R. Commercialization level and determinants of market participation of smallholder wheat farmers in Northern Ethiopia. Afr J Sci Technol Innov Dev. 2022;14(2):428–39.
53. Endalew B, Aynalem M, Assefa F, Ayalew Z. Determinants of wheat commercialization among smallholder farmers in Debre Elias Woreda, Ethiopia. Adv Agric. 2020;2020(1):2195823. https://doi.org/10.1155/2020/2195823.
54. Abu BM, Sarpong DB, Osei-Asare YB, Okyere CY, Kim T. Determinants of an extended metric of agricultural commercialization in Ghana. Sci Afr. 2024. https://doi.org/10.1016/j.sciaf.2024.e02412.
55. Hillesland M, Doss C, Slavchevska V, Querejeta M. Who claims the rights to livestock? Gendered patterns of asset holdings in smallholder households in Uganda. International Journal of Agricultural Sustainability. 2023;21(1):2220929. https://doi.org/10.1080/14735903.2023.2220929.
56. Njuki J, Mburu S, Ndhiwa N. Gender, livestock and other asset ownership. In: Njuki J, Waithanji E, Lyimo-Macha J, Kariuki J, Mburu S, editors. Women, livestock ownership and markets: Bridging the gender gap in eastern and southern Africa. London: Routledge; 2013. p. 168.
57. Tegebu FN, Mathijs E, Deckers J, Haile M, Nyssen J, Tollens E. Rural livestock asset portfolio in Northern Ethiopia: a microeconomic analysis of choice and accumulation. Trop Anim Health Prod. 2012;44:133–44.
58. Debela BL. Factors affecting differences in livestock asset ownership between male-and female-headed households in Northern Ethiopia. Eur J Dev Res. 2017;29:328–47. https://doi.org/10.1057/ejdr.2016.9.
59. Tavenner K, Crane TA. Gender power in Kenyan dairy: cows, commodities, and commercialization. Agric Hum Values. 2018;35(3):701–15.

60. Stifel D, Minten B. Market access, well-being and nutrition: evidence from Ethiopia. World Dev. 2017;90:229–41.
61. Barham J, Chitemi C. Collective action initiatives to improve marketing performance: lessons from farmer groups in Tanzania. Food Policy. 2009;34(1):53–9.
62. Aku A, Mshenga P, Afari-Sefa V, Ochieng J. Effect of market access provided by farmer organizations on smallholder vegetable farmer's income in Tanzania. Cogent Food and Agriculture. 2018;4(1):1560596. https://doi.org/10.1080/23311932.2018.1560596.
63. Greene S, Pertaub D, McIvor S, Beauchamp E, Philippine S. Understanding local climate priorities: Applying a gender and generation focused planning tool in mainland Tanzania and Zanzibar. International Institute for Environment and Development. 2020. http://www.jstor.org/stable/resrep29063. Accessed 22 Nov 2024.
64. Nnko HJ, Gwakisa PS, Ngonyoka A, Estes A. Climate change and variability perceptions and adaptations of pastoralists' communities in the Maasai Steppe, Tanzania. J Arid Environ. 2021;185:104337. https://doi.org/10.1016/j.jaridenv.2020.104337.
65. Gao J, Mills BF. Weather shocks, coping strategies, and consumption dynamics in rural Ethiopia. World Dev. 2018;101:268–83.
66. Kubik Z, Maurel M. Weather shocks, agricultural production and migration: evidence from Tanzania. J Dev Stud. 2016;52(5):665–80.
67. Asfaw S. Market participation, weather shocks and welfare: evidence from Malawi. 2018. https://ideas.repec.org/p/ags/iaae18/277029.html
68. Dzanku FM. Food security in rural sub-Saharan africa: exploring the nexus between gender, geography and off-farm employment. World Dev. 2019;113:26–43. https://doi.org/10.1016/j.worlddev.2018.08.017.
69. Madududu P, Madzokere F, Jambo N, Ruzhani F. Determinants of agricultural commercialization in smallholder farmers in zimbabwe: the case of zhombe North rural district. J Dev Agric Econ. 2022;14(3):95–104.
70. Mirie T, Zemedu L. Determinants of market participation and intensity of marketed surplus among Teff producers in Dera district of South Gondar Zone, Ethiopia. J Dev Agricultural Econ. 2018;10(10):359–66.
71. Mdoe N, Mlay G, Isinika A, Boniface G, Magomba C. Livestock, crop commercialization and poverty reduction in crop-livestock farming systems in Singida region, Tanzania. 2022.

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