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Market participation and pastoral welfare in drought-prone areas: A dose-response analysis

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ABSTRACT

The low market participation of pastoral livestock producers is a challenge to the development of a climate-resilient economy in drought-prone areas. Without deliberate and well-designed efforts to transform livestock production into a thriving profit-oriented commercial business, the development of pastoral societies will remain far-fetched. By applying bivariate selection model and dose-response function to a case study of 357 pastoral households in Ethiopia, this study examines pastoralists' participation in goat markets and the impact of participation on *per capita* income, poverty headcount, and poverty gap. Our results show that the propensity and intensity of participation of pastoralists in goat marketing were influenced by flock size, transaction costs (TC), and access to veterinary services. An important finding in this study is that pastoralists are willing to pay for marketing services up to 97 % of the total variable TC, indicating the financial feasibility of public investment in the development of market infrastructure through cost recovery schemes. The results also reveal that participation in goat marketing has a positive impact on *per capita* income, poverty headcount, and poverty gap. These findings shed some light on more practical strategies for poverty reduction among pastoralists.

1. Introduction

Governments channel policies mainly through the input-output markets to improve the welfare of rural households (Bellemare and Barrett, 2006; Balagtas et al., 2007). Market participation has important implications for the transformation of smallholder production, consumption, and livelihood strategies. Increasing market participation has been recognized to play a key role in pulling rural households out of poverty and transforming the agriculture sector in developing countries (Manda et al., 2020; Li et al., 2023; Phiona and Ambrose, 2023). The market opportunities are expanding due to the increase in the demand for livestock products (Delgado, 1998). Therefore, increasing participation in livestock markets is a key factor in pulling rural households out of poverty, as they are the owners of at least three-quarters of the livestock in developing countries (Lapar et al., 2003; Herrero et al., 2013).

In Ethiopia, livestock production contributes approximately 40 % of the agricultural gross domestic product (agGDP) and 20 % of the country's GDP (MoA, 2015; Shapiro et al., 2017). Ethiopia has Africa's largest livestock population, with about 65 million cattle, 40 million sheep, 51 million goats, 8 million camels, and 49 million chickens in 2020 (CSA, 2021). Goats are important in terms of their contribution to agGDP (Shapiro et al., 2017). They contribute to building and reinforcing risk-coping capabilities of agro-pastoral and

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pastoral communities - known for fragile livelihoods due to frequent droughts. It is also important to note that because goats have high liquidity, agropastoral and pastoral producers tend to use goat marketing as part of their drought-risk coping strategies (Barrett et al., 2004).

Meanwhile, livestock production is threatened by changes in climate, through rising temperatures and unpredictable weather patterns, while emissions from livestock are contributing to climate change (Bonilla-Cedrez et al., 2022). In Ethiopia, livestock contributes the largest share of greenhouse gas (GHG) emissions averaging about 40 % of the total national emissions (MoA, 2015). Several studies show that improving productivity and increasing the diversity of the herd could help reduce GHG emissions (Gerber et al., 2013; Koluman (Darcan) Nazan and Silanikove, 2017). Goats are not only low-emitting animals compared to other species (e.g., sheep and cattle) but also contribute low enteric emissions per kilogram of meat particularly in sub-Saharan Africa (Gerber et al., 2013). Hence, Ethiopia's green economy initiatives consider goats as the most important component of the process of building a climate-resilient economy. The initiatives also point out the importance of improving value chain efficiency in reducing emissions, for example, through improving the low level of animal offtake rate by decreasing the age at which goats are sold.

Market-based livestock production and, therefore, improved and systematic livestock market participation shall be an important consideration in building a climate-resilient economy in Ethiopia. This is more important, particularly for those who depend heavily on their livestock. Although market-oriented production and increased participation in livestock marketing can improve the welfare of livestock keepers, the level of livestock keepers' market participation remains low in rural Ethiopia (Barrett et al., 2004; Bellemare and Barrett, 2006). Several constraints and barriers contribute to reducing incentives for smallholder producers' participation in livestock markets in sub-Saharan Africa. Studies so far revealed that imperfect market and lack of financial and physical capital are the main constraints to participating in the livestock markets (Burke et al., 2015; Abay and Jensen, 2020; Kassie et al., 2022).

Market imperfections can be attributed to high transaction costs (TCs), including both fixed and variable costs. The source of households' income (financial capital) and the number of livestock owned (physical capital) are potentially endogenous to pastoralists' livestock marketing strategies. Access to the market and veterinary services also play an important role in the decision of pastoralists to participate in livestock markets. For example, Abay and Jensen (2020) documented that the participation of livestock keepers significantly responds to the conditions in livestock markets. The study by Terfa (2012) also showed that access to veterinary services helps to increase the size and stability of flock sizes and hence wealth, which, in turn, contributes to reducing impulsive marketing.

A noteworthy, but usually overlooked, point in modeling livestock marketing is that livestock producers participate in the livestock market not only to sell for generating cash for immediate needs but also to buy for restocking their herd that might have dwindled due to severe drought or to reinforce existing herd. Therefore, to capture the endogenous participation decisions of pastoralists in the model, their main marketing strategies should be considered. Very few studies consider pastoralists' decisions to participate in livestock markets from both buying and selling angles (Bellemare and Barrett, 2006; Burke et al., 2015). Another development in analyzing livestock marketing is conceptualizing marketing decisions through the classification of livestock producers based on their sales balance as net sellers, net buyers, or autarkic by subtracting the quantity purchased from the quantity sold (Bellemare and Barrett, 2006). Although pastoralists are generally net sellers, they also engage in strategic marketing to purchase livestock. Therefore, in this study, we focus on understanding pastoralists' market participation decisions for both purchasing and selling. The information obtained from such an approach is important in developing strategies to make the market work better for pastoralists.

The purpose of this paper is two-fold. We seek to investigate the drivers of pastoralist market participation in a way that takes into account the potential endogeneity of participation decisions. We also examine whether marketing interventions increase the participation of pastoralists in the market and contribute to lifting them out of poverty.

To address the issue of endogeneity of market participation decisions, we model both discrete and continuous market participation decisions using simultaneous estimation methods. We will also verify whether pastoralists' decisions to sell and buy are simultaneous or sequential. We employ a bivariate selection model that captures selection bias related to the unobserved marketing behavior of pastoralists around selling and buying goats. In the first stage, we model pastoralists' market participation as a discrete decision using bivariate probit. We then use the dose-response model to address the second objective of the study, examining the impact of market participation on *per capita* income, poverty headcount, and poverty gap.

This paper contributes to the literature on pastoralists' market participation by focusing on the potential effect of financial and physical capital, TCs, market conditions, and access to veterinary services on market participation. Our findings showed that the size of the flock, TC, and access to veterinary services affect pastoralists' decisions to participate in goat marketing. The variable TC has a quadratic relationship with pastoralists' decisions to participate in the market. We also found that participation in goat marketing has a significant impact on *per capita* income, headcount ratio, and poverty gap. Our findings will be useful for policymakers and development practitioners who are eager to improve the welfare of pastoralists in Ethiopia and similar communities in sub-Saharan Africa.

The remainder of this manuscript is organized as follows. Section 2 describes conceptual and empirical frameworks. Data and a description of the study area are presented in section three, while section four provides the results and discussion. Finally, section five concludes and presents some policy suggestions.

2. Conceptual and empirical frameworks

Here we describe the interdependence of participation decisions to sell and to buy goats and the factors driving these decisions. We also briefly explain how market participation improves pastoral welfare. Pastoral welfare is measured with *per capita* income and poverty indicators (headcount ratio and poverty gap). The conceptual framework of this study follows the approaches developed and tested by Bellemare and Barrett (2006) and Camara et al. (2023). Pastoral households are involved in both selling and purchasing goats and hence their decisions to sell and to buy are interrelated and can be simultaneous or sequential. Literature on market participation

shows that household demographic characteristics, asset endowment, transaction costs (that are potentially associated with the development of market infrastructure), and institutions (such as access to services) are important factors driving participation (von Braun, 1995; Barrett, 2008; Phiona and Ambrose, 2023). As argued by von Braun (1995) the participation of smallholder producers in the output (sales) market leads to increased household income, which can be partially translated into reducing the level of poverty.

The theoretical models of marketing behavior are formalized based on the agricultural household model (AHM). In the AHM, the household is both a producer, choosing the allocation of labor and other inputs to crop production, and a consumer, choosing the allocation of income from farm profits and labor sales to the consumption of commodities and services (Taylor and Adelman, 2003; LaFave and Thomas, 2014). The model specifically assumes that farm households are not pure profit-maximizing producers, and therefore their production, consumption, and marketing decisions are interdependent or inseparable (Bardhan and Udry, 1999; Le, 2010). Pastoralists' engagement in the market is not meant for profit maximization, rather it is an instrument for regulating herd size and for coping with different shocks that they face in the production and marketing of their livestock (Lybbert et al., 2004). We thus consider the market participation decisions to buy and to sell animals as interrelated. The empirical models highlight the implications of different assumptions about the process of household market participation decisions. Double hurdle modeling is a well-known approach in the marketing literature (Key et al., date; Goetz, 1992; Holloway, 2000, 2005; Bellemare and Barrett, 2006). This analytical framework assumes that smallholder producers first decide to sell or buy a particular commodity and then determine the volume of sales or purchases. In a situation where the selection bias associated with the decision of pastoralists to rear goats is insignificant, market participation decisions can be modeled as a two-step (double hurdle) process.

To the extent that the purposes of goat rearing among producers are wide-ranging - including consumption, income generation, wealth accumulation, and risk coping, their decision to buy may depend on the decision to sell goats, and vice versa. For example, to restock or increase the number of young reproductive animals in the herd, pastoralists sell a few adult animals to generate sufficient cash. These sale and purchase decisions are clearly non-separable specifically for those who are liquidity-constrained, and this is the rationale behind our hypothesis of endogenous market participation decision. Therefore, the error terms of the annual sales and purchases equations are expected to be correlated. In addition, modeling livestock marketing inherently suffers from selection bias due to unobservable characteristics such as pastoralists' price expectations and negotiation skills. These factors are also potential causes of endogeneity.[1]

We employ conditional mixed process modeling to account for the endogeneity of market participation decisions (i.e., the correlation between random terms in the purchasing and selling decision equations) by jointly estimating the equations of sales and purchases (Roodman, 2011). As presented in Fig. 1A and 2A in the appendix, the distributions of the intensity of participation of pastoralists in goat purchasing and selling are substantially censored at zero. Bivariate models provide a better way of using sales and purchase data to explicitly analyze the participation of agents while addressing selection bias. Therefore, we apply a two-stage bivariate model estimation to control for selection bias.

We begin by treating the participation decision as discrete and estimate a bivariate probit model in the first stage to examine factors driving pastoralists' participation in the market to sell or buy. In the second stage, we estimate a bivariate regression model to explain the determinants of the individual decisions on the number of goats to be sold or purchased. When estimating the intensity of participation, we correct selection bias by incorporating the coefficient of the inverse Mills ratio (IMR).[2] Note that although we capture IMR in the second stage, the model we proposed accounts for the correlation of the error terms due to endogenous market participation decisions and hence differs from the ordinary Heckman Selection Model (Gillespie and Mishra, 2011).

In the first stage we specify the bivariate probit model, following Cappellari and Jenkins (2003), as follows:

$$\begin{aligned} &y_{im} = 1 \ if \ y^*_{im} > 0, \ and \ 0 \ otherwise, \ m = 1, \ 2 \\ &y^*_{im} = \alpha_m + X_{im}\beta_m + \ \mu_{im} + \epsilon_{im} \end{aligned} \tag{1}$$

where m represents the number of equations - that is the decision to sell and the decision to buy; y_{im} represents pastoralist i's decision to participate in selling or buying and takes a value of 1 if the livestock producer decides to participate in the market (to buy or to sell), and 0 otherwise; X is a vector of explanatory variables, including demographic and socioeconomic characteristics, access to veterinary services, access to market, and TCs; β is a conformable vector of unknown parameters to be estimated; μ_{im} is the market fixed effects; and ε_{im} is an error term distributed as multivariate normal with mean zero, and variance-covariance matrix V, where V has values of 1 on the main diagonal, and correlations $\rho_{jk} = \rho_{kj}$ as off-diagonal elements.

In the second stage, we examine the decision on the intensity of market participation by employing a bivariate regression model that can be specified as follows.

$$z_{im} = \alpha_m + X_{im}\beta_m + IMR_{im} + \mu_{im} + \varepsilon_{im}, \ where \ m = \ 1, \ 2 \tag{2}$$

where z_{im} is the quantity individual producer `i' sold or bought; IMR_{im} is the inverse mills ratio estimated from Eq. (1); and μ_{im} is the market fixed effects. Due to the unobserved marketing behavior of pastoralists and their endogenous market participation decisions, it

[1] Endogeneity problems can arise due to both endogenous market participation decisions and endogenous selection bias. The endogenous market participation decision refers to the fact that pastoralist decisions to sell and buy are more likely to be endogenous, and hence the error term of the decision to sell is expected to be correlated with that of the decision to purchase. However, endogenous selection bias refers to the economic decision of pastoralists to participate in the market, which is unobserved by researchers.

[2] The IMR is estimated from the discrete purchasing and selling equations to control for selection bias in the second- stage estimation.

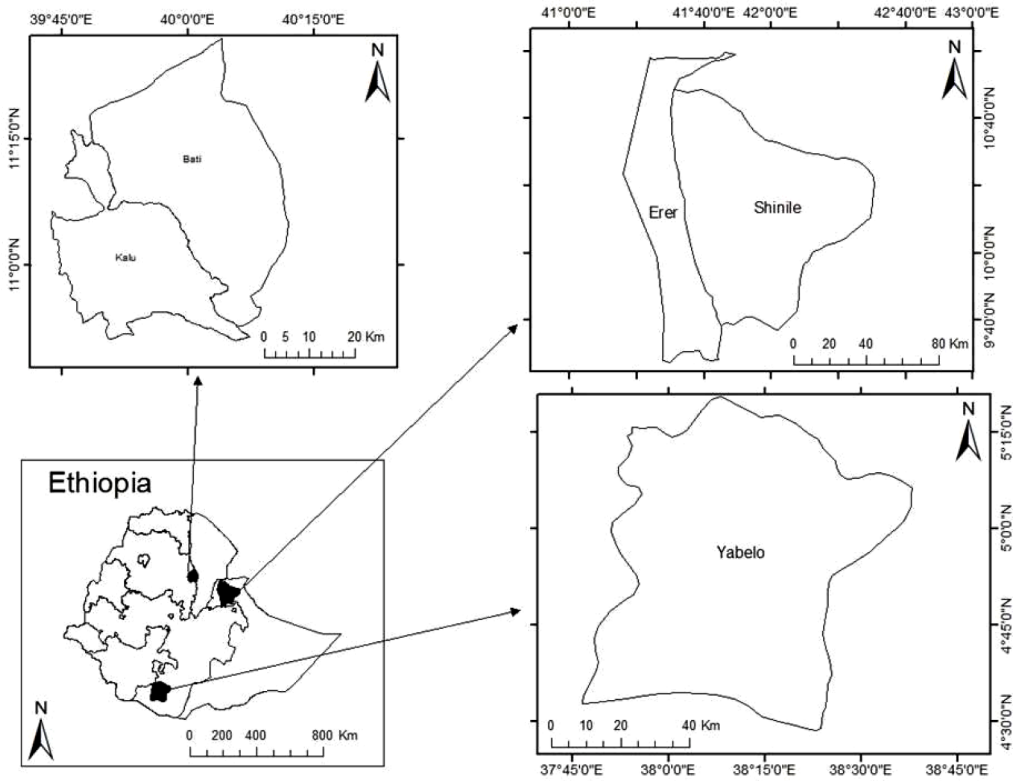


Fig. 1. Location of the study areas. *Note*: The study was conducted in three regions targeting the major goat markets in each region. As shown in the figure, Bati and Kalu are adjacent districts in Amhara region and the nearest goat market is Bati. Similarly, Shinile and Erer are adjacent districts in the Somali region and the nearest goat market is Dire Dawa. Yabelo district is in the Oromia region, where Borena market is situated. Bati, Dire Dawa, and Borena markets are the largest goat markets in Amhara, Somali, and Oromia regions, respectively.

is expected that both the IMR coefficient and the correlation coefficient of the error terms will be different from zero. The conditional mixed process (cmp), which essentially uses the seemingly unrelated regressions modeling framework, helps us to account for these selection bias and endogeneity problems (Roodman, 2011).

We also estimate the impact of selling goats on *per capita* income, headcount ratio, and poverty gap. In doing so, we assume that the effect of market participation in reducing poverty is likely to be different depending on the level of participation. The change in the level of poverty depends on the extent (or dose) of participation in the market, instead of the propensity to participate. We consider the individual's minimum dietary needs to measure poverty, where, for the sake of robustness, we use the upper poverty line of 3781 Ethiopian Birr (ETB)[3] per adult equivalent per year suggested by the Ethiopian Central Statistics Authority in 2015. The poverty measures we are considering are poverty headcount, and poverty gap. Poverty headcount shows the poverty status of a household in terms of whether it is below the poverty line, and the poverty gap indicates the intensity of poverty in terms of how far the household is below the poverty line. To estimate the poverty measures, we use Foster et al. (1984) index, given as:

$$FGT_\tau = \frac{1}{N}\sum_{i=1}^{M}\left[\frac{pl - pc_i}{pl}\right]^\tau \tag{3}$$

where N is the total number of people in a household, pl is the poverty line, pc_i is the *per capita* income of individual household *i*, and τ is the parameter of poverty aversion. When $\tau = 0$, FGT_τ is simply the headcount index that shows the proportion of households that are poor. When $\tau = 1$, FGT_τ is the poverty gap index, defined by the mean distance to the poverty line reflecting the depth of poverty.

We estimate the impact of participation on poverty using the dose-response function (DRF) (Cerulli and Ventura, 2020). Therefore, we consider the level of participation of the market in the goat market as a treatment variable, providing a dose of greater than 0 if the pastoralists decide to participate in goat sales and 0 otherwise. By considering the treatment status in Eq. (1) above, we specify the model as follows:

[3] At the time of the study, the currency exchange rate was: 1US$ = 18.66 ETB.

Table 1
Variables and descriptive statistics.

Variable	Definition of variables	Mean	Std. Dev.
Decision to sell	1 if a household participates only in selling, 0 otherwise.	0.68	0.31
Decision to sell and to buy	1 if a household participates in selling and purchasing, 0 otherwise	0.29	0.44
Decision to purchase	1 if a household participates only in purchasing, 0 otherwise.	0.03	0.17
Quantity sold	Number of goats sold	5.8	0.62
Quantity bought	Number of goats purchased	1.1	0.25
PCI/year	*Per capita* income (ETB)/year	3768	5067
Headcount	1 if a household is poor, 0 otherwise	0.72	0.45
Poverty Gap	Mean distance to the poverty line	0.39	0.27
Gender of household head	1 if the head of household is male, 0 otherwise	0.82	0.39
Age of the household head	Age of the household head (years)	44.55	13.33
Household size	Number of people in a household	7.16	2.74
Share of goats	Share of goats in total livestock owned (%)	26.33	30.24
Share of cattle	Share of cattle in the total livestock owned (%)	51.91	35.17
Fixed cost	Transport and related costs for household	30.21	67.85
Variable cost	members participating in goat marketing (ETB) Cost of transactions, including taxes and animal transportation (ETB)	38.27	82.60
Access to veterinary services	1 if a household has access to veterinary services, 0 otherwise	0.83	0.38
Having mobile phone	1 if a household owned mobile phone, 0 Otherwise	0.54	0.50
Distance to market	Time taken to market in walking minutes	13.82	8.54

Note: The share of goats in the total livestock owned indicates the economic decisions of pastoralists on how many goats they keep given the resources they have. Therefore, the share of goats in the total livestock owned helps to see to what extent goats are important to pastoralists. The share of goats is computed as the goats owned in Tropical Livestock Unit (TLU) divided by the total livestock owned (in TLU) multiplied by 100. The share of goats is determined not only by the number of goats purchased and sold, but also the number of other livestock species purchased and sold. The conversion ratio of TLU is as follows: 1 camel = 1.43; 1 cattle = 1.0; 1 equine = 0.8; 1 goat = 0.1; and 1 sheep = 0.09 (Bellemare and Barrett, 2006).

$$\begin{aligned} y &= 1: \; q_{1i} = \alpha_{1i} + X_{1i}\beta_1 + h(t) + \varepsilon_{1i} \\ y &= 0: \; q_{0i} = \alpha_0 + X_{0i}\beta_0 + \varepsilon_{0i} \end{aligned} \tag{4}$$

where q_{1i} and q_{0i} are the outcome variables for individual pastoral households who participated and who did not participate, respectively. $X_{1i}\beta_1$ and $X_{0i}\beta_0$ are response functions with and without market participation, respectively. $h(t)$ is the treatment, taking the continuous values in the range 0 to 100. We define $h(X_i)$ as the response to a given level of treatment (t) conditional on the covariate X for individual pastoralist i. The DRF is therefore defined as an average treatment effect (ATE) estimated at each value of treatment (t) as $ATE = (q_{1i} - q_{0i})$. We can specify the ATE conditional on X and t as:

$$ATE\ (X,\ t,\ y) = y * \left[\alpha + X_{i\beta} + h(t)\right] + (1-y) * \left[\alpha + X_{i\beta}\right] \tag{5}$$

where $\alpha = (\alpha_1 - \alpha_0)$ and $\beta = (\beta_1 - \beta_0)$.

We use a linear regression model as applied by Cerulli and Ventura (2020), to estimate the ATE, leading to the following DRF:

$$q_i = \alpha + y_i * ATE + X_i\beta_0 + y_i * (X_i - \overline{X})\beta + y_i * (h(t_i) - \overline{h}) + \eta_i \tag{6}$$

where $\eta_i = \varepsilon_{0i} + y_i * (\varepsilon_{1i} - \varepsilon_{0i})$.

3. Data and description of variables

We used a multistage sampling method to select study areas and sample households. First, we used a purposive sampling approach to select three main goat marketplaces from drought-prone districts of the Amhara, Oromia, and Somali regions of Ethiopia. The selected districts, namely Bati, Erer, Kalu, Shinile, and Yabelo, are characterized by erratic rainfall and recurrent drought (see Fig. 1). Then, twenty *Kebeles* (the smallest administrative unit in the country) were randomly selected from these districts. Finally, we randomly selected pastoral households from each *Kebele* proportional to their respective population sizes. Our sample size calculation resulted in 357 units for the statistical power of our interest.[4] We interviewed 357 pastoral households in 2014. We have 118 observations from the Bati market in the Amhara region, 115 from the Dire Dawa market, and 124 from the Borena market in the Oromia region. Structured questionnaires were used to collect demographic and socioeconomic characteristics of households, TCs, sales and purchase prices of goats, and the number of sales and purchases of goats. The number of sales and purchases represents the annual

[4] We followed Cochran's formula for categorical data to yield a representative sample size proportion and the power analysis is as follows: $n_0 = \frac{z^2pq}{e^2}$, where n_0 is the sample size; z is the abscissa of the normal curve that cuts off an area α at the tails (leading to the desired confidence level of $1 - \alpha$, i.e., 95%), which has a tabulated value of level 1.96; e is the desired precision (in our case 5 %); p is the estimated proportion of market participants in pastoralist areas, i.e., 34%, and q is $1 - p$.

Table 2
Estimates of pastoralists' participation decisions in the goat markets.

	Decision to sell		Decision to buy	
	Coefficient (1)	*dy/dx* (2)	Coefficient (3)	*dy/dx* (4)
Male-headed households	−0.022	−0.005	−0.185	−0.048
	(0.231)	(0.048)	(0.222)	(0.058)
Age of the head of household in years	−0.011	−0.002	0.006	0.002
	(0.007)	(0.002)	(0.007)	(0.002)
Household size in adult equivalent	0.121**	0.025**	−0.041	−0.011
	(0.062)	(0.013)	(0.048)	(0.012)
Share of goats (%)	0.001	0.001	0.007**	0.002**
	(0.003)	(0.001)	(0.003)	(0.001)
Log of fixed cost	−0.168***	−0.035***	−0.170***	−0.044***
	(0.065)	(0.013)	(0.053)	(0.013)
Log of variable cost	0.796***	0.166***	−0.745***	−0.194***
	(0.265)	(0.054)	(0.210)	(0.052)
Log of variable cost squared	−2.21***	−0.461***	2.88***	0.750***
	(0.623)	(0.125)	(0.529)	(0.122)
Access to veterinary services	−0.766***	−0.160***	0.283	0.074
	(0.279)	(0.057)	(0.247)	(0.064)
Having a mobile phone	0.193	0.040	0.317*	0.082*
	(0.180)	(0.037)	(0.177)	(0.045)
Log of distance to market	−0.241	−0.050	−0.142	−0.037
	(0.162)	(0.034)	(0.132)	(0.034)
Constant	2.16***		−1.24***	
	(0.665)		(0.570)	
Correlation of error terms	0.624***			
	(0.177)			
Observations	343			

Note: ***, **, and * denote statistical significance at $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively. Columns 2 and 4 are the coefficients of the bivariate probit model, while columns 3 and 5 present the marginal effects. The household size is reported in terms of adult equivalence (AE). Numbers in brackets are the standard error. We estimate the standard errors of the marginal effects using the Delta method.

transactions, while the selling and buying prices represent the annual average prices.

We defined sales in our data set as the total number of goats sold by a household. Similarly, purchase is defined as the total number of goats purchased by a household. Data on income from goat rearing included only cash income obtained from goat sales. Data collected on TCs included fixed and variable costs. Fixed costs are invariant to the amount of transaction and include transport for household members participating in goat marketing and specific types of broker costs. Variable costs are costs per unit of goat transaction and include transportation costs, lodging fees, taxes (utility charges), and broker fees. Although pastoralists transport goats to and from the market by contracting a vehicle on their own or sharing with others, transportation costs are charged per animal.

Table 1 presents descriptive statistics of household characteristics and important variables related to market participation. About 82 % of the sample households were male-headed, with an average age of 45 years. The typical household in the sample consisted of about seven family members and an average *per capita* income of 3768 ETB/year. Goats constitute 26 % of total livestock owned by pastoralists, making them the second most important species after cattle (51.9 %). Eighty percent of households participated in goat marketing, with 68 % only in sales, 3 % only in purchases, and 29 % in both. The average numbers of goats sold and purchased in a year were 5.8 and 1.1, respectively. The average headcount ratio among sample pastoralists was about 72 %, and the poverty gap index was 39 %.[5] The average variable TC was 38 ETB/head constituting 64 % of the total TC.[6] About 83 % of the sampled households had access to veterinary services and 54 % of households owned mobile phones.

4. Results and discussion

4.1. Tests on the specification of the model

By conceptualizing market participation decisions as three-stage processes (Burke et al., 2015; Fan and Garcia, 2017), we test whether the prior decision (production decision) correlates with the next (market participation decision). In the triple hurdle model (Burke et al., 2015) livestock market participation is modeled as a three-stage process. In this model, the decision of households whether to participate in goat rearing is first modeled. Then, for those who decided to produce goats, it is modeled as a two-stage process. In our data set, the distribution of pastoralists' decision to keep goats or otherwise is binary and skewed towards rearing.

[5] The poverty headcount ratio of the selected districts in the three different regions is higher than the national headcount ratio by 8%. The national multidimensional poverty index is approximately 43% (https://bit.ly/42VPtuB).

[6] As stated earlier, the total transaction costs equal the sum of variable and fixed transaction costs.

Table 3
Determinants of the extent of market participation in goat marketing.

	Quantity sold Coefficient (St.err.)	Quantity bought Coefficient (St.err.)
Male-headed households	0.735	−1.02**
	(0.784)	(0.407)
Age of the head of household in years	0.013	0.027***
	(0.027)	(0.012)
Household size in AE	0.144	−0.273***
	(0.186)	(0.079)
Share of goats (%)	−0.005	0.028***
	(0.011)	(0.009)
Log of fixed cost	0.023	−0.869***
	(0.252)	(0.218)
Log of variable cost	6.47***	−1.95**
	(1.12)	(0.912)
Log of variable cost squared	−14.9***	10.47***
	(2.90)	(3.50)
Access to veterinary services	−1.34	1.46***
	(1.09)	(0.462)
Having a mobile phone	1.35**	1.54***
	(0.643)	(0.443)
Log of distance to market	1.16***	−0.896***
	(0.478)	(0.255)
IMR of sale	0.279	
	(3.25)	
IMR of purchasing		5.22***
		(1.60)
Constant	0.493	−7.66
	(1.91)	(2.86)
Correlation of error terms	0.134	
	(0.055)	
Observations	343	

Note: ***, **, and * denote statistical significance at $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively. Column 2 contains the coefficients of the quantity of goat sold in a year model, while column 3 contains that of the quantity of goat bought in a year. As in Table (2), we include the quadratic term of the variable cost in the model estimation. Market fixed effects are controlled in both estimations. The household size is reported in terms of adult equivalent. AE stands for adult equivalent. Numbers in brackets are the standard error.

Therefore, we ran a complementary log-log regression to estimate the pastoralist production decision. The estimates are presented in Table 1A in the Appendix. To ascertain whether two- or three-stage modeling fits our dataset, we estimate the model specified in Eq. (1) by including the inverse Mill's ratio (IMR) generated from the estimation of the production decision model. The results show that there is no statistically significant correlation between the decisions to produce goats and to participate in the market, suggesting the standard double hurdle model is more appropriate (Table 2A in the Appendix).

The estimates of the bivariate regression model are presented in Tables 2 and 3. The correlation coefficients of the error terms from both bivariate probit and bivariate regression models are found to be statistically significant, showing endogeneity in both the propensity and intensity of market participation. Decisions to participate in goat sales and the number of sales for those who chose to participate are affected by the decision and the extent of purchases, respectively, or vice versa. The results are also intuitive since the decisions and quantity of transactions are annual aggregates that are likely to account for all possible scenarios throughout the year, such as family consumption, liquidity requirements, breeding and restocking, and stochastic variables (weather and prices). The estimate from the bivariate linear regression is also consistent in showing the existence of selection bias in the decision to buy and sell, indicating the need for correction.

4.2. Propensity to market participation

Table 2 presents the results of the bivariate probit model (Eq. (1)). The second column presents the coefficients of the model for propensity to participate in goat selling, and the fourth column presents that of the decision to buy. The results show that larger households are more likely to engage in goat sales than in goat purchases, implying that pastoralists with large families are more net sellers than others. A possible explanation for the higher propensity of larger households to sell more goats is that larger families are more likely to have greater financial pressure to meet pressing needs, such as purchasing food items, including cereals and legumes. In the face of low on-farm and off-farm employment opportunities among pastoral communities, larger households are expected to have less liquidity to participate in the purchase of goats at least to a considerable level.

Pastoralists with a large share of goats in their livestock are more likely to buy goats. The plausible explanation is that households that specialize in goat rearing generate cash from milk selling or use it as a means of wealth accumulation and/or a coping mechanism for any unforeseen risks. The positive effect of the share of goats on purchase could also be explained by pastoralists' practice of

replacing flocks when they get older with younger ones or restocking flocks in the aftermath of droughts and disease outbreaks. It is also useful to make note of the strategies that pastoralists employ to manage their flock sizes. For example, pastoralists who plan to sell more goats in the later part of the year may decide to build their flock by purchasing young ones earlier in the year.

Transaction costs related to transportation, marketing information services, market infrastructure, and other facilities have negative effects on pastoralist market participation decisions. Specifically, fixed TCs have a strong negative effect on pastoralists' likelihood of participating in goat sales and purchases. The negative and significant coefficient on the quadratic term of variable costs, shows that up to a certain threshold, variable TCs enhance market participation, but as they increase beyond the threshold, the propensity of pastoralists to participate in goat sales decreases. In contrast, the propensity of pastoralists to purchase goats remains high even when transaction costs increase. This finding could be explained by the need for high-quality marketing information, as pastoralists are more sensitive to changes in the purchasing price than to the selling price of goats (Yitayew et al., 2019).

We also found that access to veterinary services has a negative and statistically significant effect on participation in sales. The result is intuitive in the sense that when pastoralists do not have access to veterinary services, they tend to sell more goats to reduce risks related to morbidity. This reflects that in addition to selling goats to meet cash needs and get benefits when goat prices are high, pastoralists can use marketing as a destocking strategy to regulate their herd size. In practice, pastoralists sell animals to mitigate risk of exposure to disease outbreaks and droughts and restocking again through purchases in the aftermath of disease outbreaks and bad climatic phenomena. The study areas are characterized by unpredictable rain and recurrent droughts that often force pastoralists to engage in excessive and untimely sales. Therefore, if pastoralists expect bad weather, they will not stock their flocks before the drought. Second, if pastoralists have access to veterinary services, they are more likely to use livestock as a form of saving and sell them when faced with financial challenges. This result is in line with the findings of Wanyoike et al. (2015). The ownership of mobile phones has a positive and significant influence on the decision of pastoralists to participate in goat purchases. As indicated above, pastoralists are more sensitive to purchasing prices, and the ownership of mobile phones improves their ability to gather price information. But this is not the case with goat sales, as pastoralists are often forced to sell regardless of price levels to meet cash needs or to escape disease outbreaks and severe droughts.

4.3. Intensity of market participation

Table 3 presents the results of the bivariate linear regression model (Eq. (2)) estimating the extent of pastoralists' market participation, conditional on their decisions to sell and to buy. The results show that female-headed households are more likely to purchase higher number of goats than male-headed households. The results also reveal that the age of the household and the number of household members affect the number of purchases of goats by pastoralists. Older farmers tend to buy significantly more goats than younger farmers, while larger families have significantly fewer purchases than smaller families. The higher participation of older farmers in the purchase of goats appears to contradict the life cycle effect theory. Life cycle effects refer to how different stages in a pastoralist's life, such as youth and old, can influence their decision-making, preferences, and strategies in livelihood activities.

The results show also that the proportion of goats in the total livestock owned by a household has a positive and statistically significant effect on the number of goats purchased. This implies that as the proportion of goats in the herd increases, pastoralists tend to invest further in goats, probably to use them as a means of wealth accumulation. The ease of selling goats relative to larger animals also drives pastoralists to continue restocking their herd.

Similarly, the results confirm that the extent of market participation in sales and purchases is influenced by the magnitude of the transaction cost. The linear effect of variable cost on the intensity of goat sales is positive and statistically significant. However, its effect on the intensity of goat purchases is negative and statistically significant. These findings are expected because pastoralists' buying decisions are more responsive to changes in costs than selling decisions. These results are in line with what Bellemare and Barrett (2006) reported in a similar study in Kenya and Ethiopia. If the variable cost passes a certain threshold, its impact on the volume of transaction becomes negative – thereby having an inverted U-shaped relationship with the intensity of participation. The quality of marketing services - such as transportation facilities, feed troughs, and sheds - is poor in Ethiopian livestock markets (Mekuriaw and Harris-Coble, 2021). Unlike variable costs, the effect of fixed costs on the number of transactions is the same for sales and purchases. Fixed costs have a negative and statistically significant impact on the number of transactions.

Although distance from the market has a negative and statistically significant influence on the number of goats purchased, its effect on the number of goats sold is positive and statistically significant. The possible factor that could drive these results is the marketing strategy that is associated with the size of the pastoralists' herd. As pastoralists are generally net sellers, they can reduce fixed costs by supplying more goats at once. However, it is less likely that fixed costs can be reduced by purchasing a higher number of goats at once. The positive effect of distance to market on the number of goats sold is in line with the findings of (Balagtas et al., 2007) in Cote d'Ivoire. It is worth noting that because animal feeds are relatively adequately available in the pastoralist areas, and increasingly so as the distance from markets (which are usually located in towns) increases, instead of net buyers and/or autarkic, pastoralists who are often located far away from the markets are more likely to be net sellers.

The effect of access to veterinary services on the number of goat purchases is positive and statistically significant. A possible explanation is that if pastoralists have access to veterinary services that help them reduce the health risk of mixing newly purchased goats into the flock, then they will be more inclined to buy more goats. We also found a positive and statistically significant effect of mobile phones on the number of goats purchased and sold, indicating that pastoralists who own mobile phones are more likely to engage in larger purchases and sales. It looks like mobile phones have enabled pastoralists to have better access to market information. In summary, although decisions to purchase are affected by sale decisions and vice versa, marketing strategies for selling and purchasing goats under normal weather and pest conditions revolve around the extent of cash need and market goat prices (Yitayew et al.,

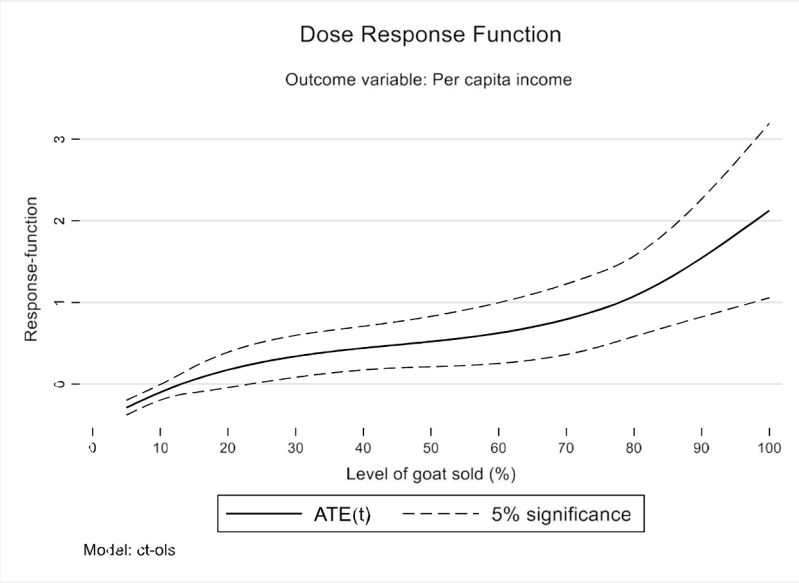


Fig. 2. Impact of market participation on *per capita* income of pastoralists (dose response).

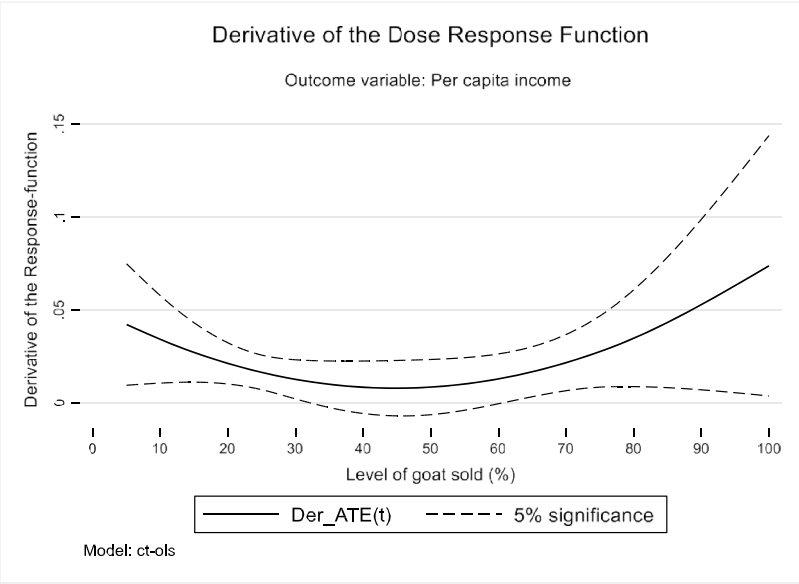
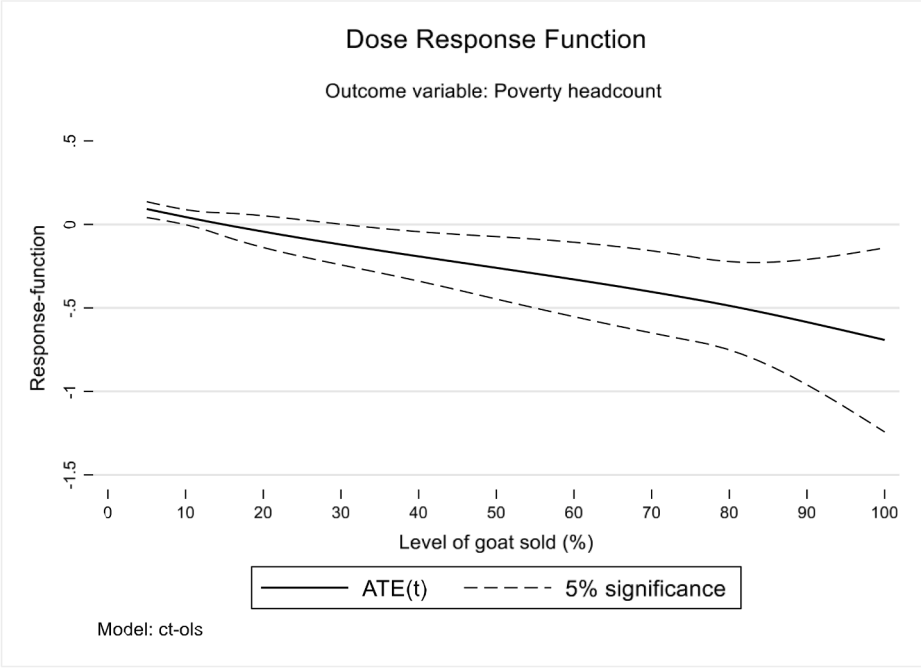


Fig. 3. Marginal effect of market participation on *per capita* income.

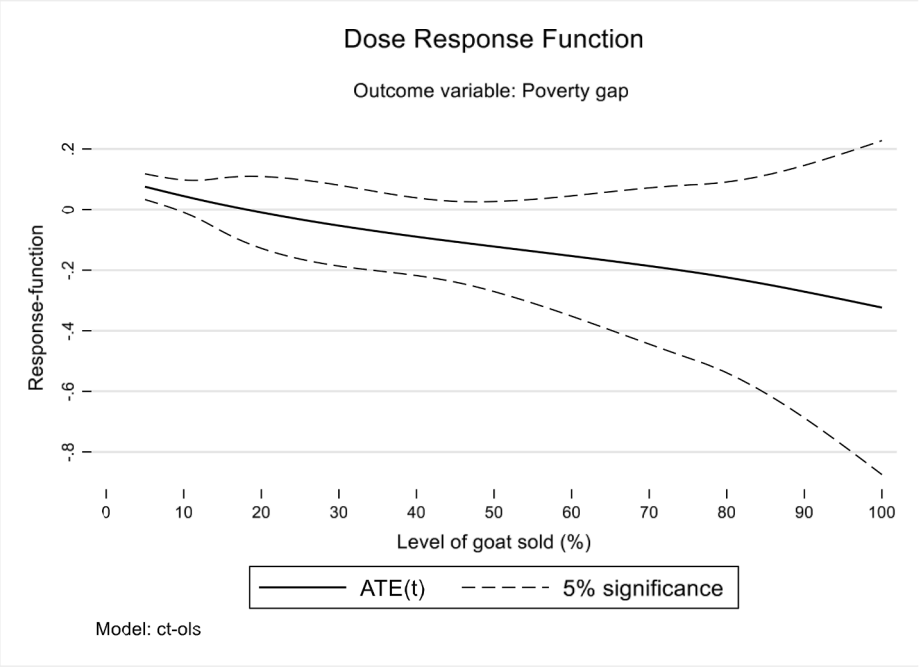
2019).

4.4. Welfare impact of goat market participation

In addition to understanding their marketing behaviors, policy makers and educators are interested in the impact of market participation on the welfare of pastoralists. Therefore, we estimate the impact of the intensity of market participation of pastoralists (as sellers of goats) on the *per capita* income and poverty measures. In Figs. 2–4, we report the dose-response of intensity of participation in the goat market on *per capita* income and poverty outcomes. We report the dose- response function (DRF) in Fig. 2, and the marginal



(a) Poverty headcount



(b) Poverty gap

Fig. 4. Estimates of response dose-response function on poverty headcount (a), and poverty gap (b).

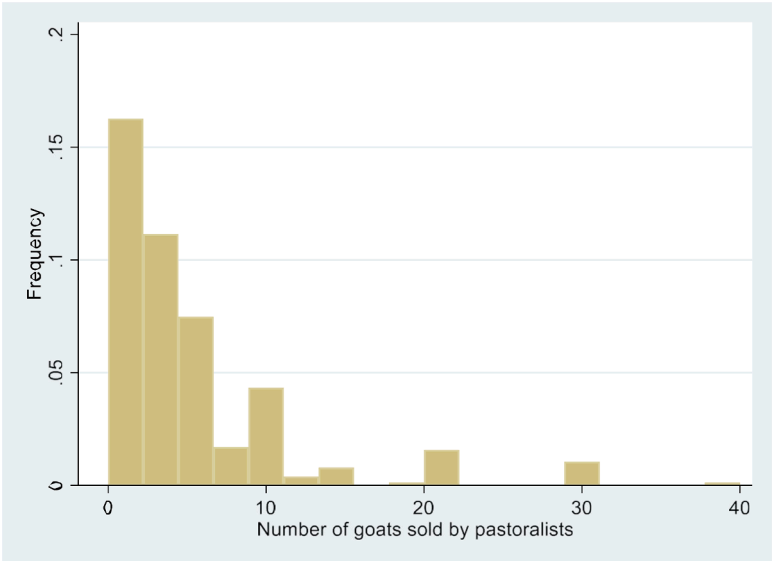


Fig. 1A. Distribution of number of goats sold by pastoralists in a year.

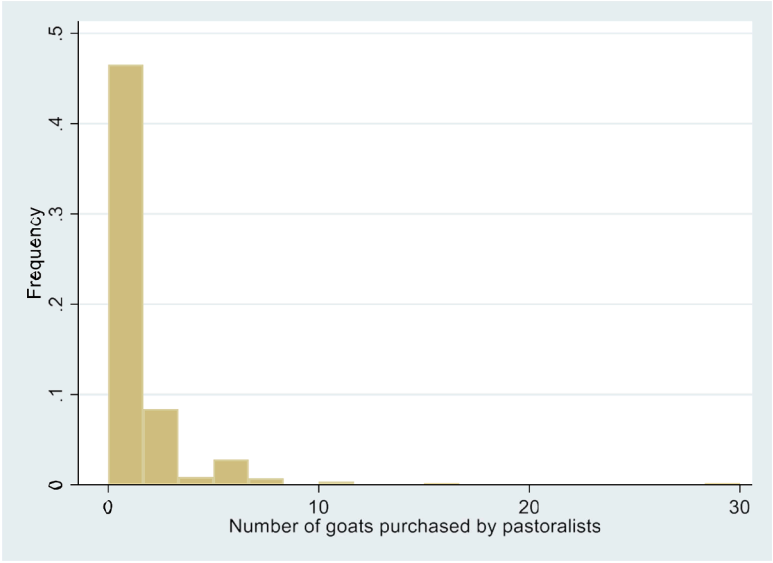


Fig. 2A. Distribution of number of goats purchased by pastoralists in a year.

effect of DRF (i.e., intensity of market participation) on *per capita* income in Fig. 3. The DRF reveals that *per capita* income increases with the percentage of goats sold, which is consistent with the treatment effects in Fig. 3A in the Appendix. The marginal effect of DRF shows that the increase in *per capita* income occurs only when the number of goats sold increases by at least 45 percentage points.

Fig. 4 below shows the DRF results for the poverty outcomes, i.e., headcount ratio and poverty gap.[7] The graphs generally indicate an inverse relationship between the number of goats sold and poverty outcomes. This indicates that poverty decreases as the level of goats sold moves from low to higher intensity levels, which is consistent with the findings of Ojong et al. (2022) in their study conducted in Ethiopia. They found that agricultural commercialization has a positive impact on assets and income. The result of poverty outcomes, specifically regarding the poverty gap, indicates that the number of goats sold should increase substantially for the intensity of poverty among pastoralists to decrease. Similarly, a study by Li et al. (2023) has also shown that maize farmers market participation significantly improved their subjective and objective wellbeing.

[7] For brevity, we report the dose-response estimates of poverty severity in the Appendix in Fig. 4A. We use FGT indices to estimate severity of poverty. As indicated above, FGT_τ shows the severity of poverty or the extent of inequality when $\tau = 2$.

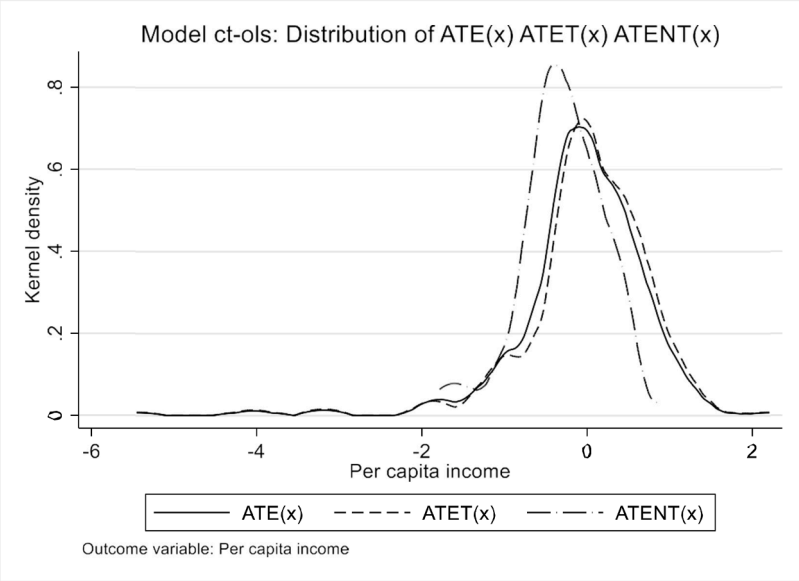


Fig. 3A. Average treatment effect on *per capita* income on all sample (ATE), treated (ATET), and non-treated (ATENT). Note: Fig. 3A presents the treatment effects by comparing the *per capita* income of the participant and non- participant pastoralists in the goat markets. The plot shows that the distribution of average treatment effect on the treated (ATET) is to the right of the distribution of average treatment effect (ATE) and average treatment effect on the untreated (ATENT) indicating that the mean *per capita* income of the participant pastoralists is higher than that of the nonparticipants and the total sample average.

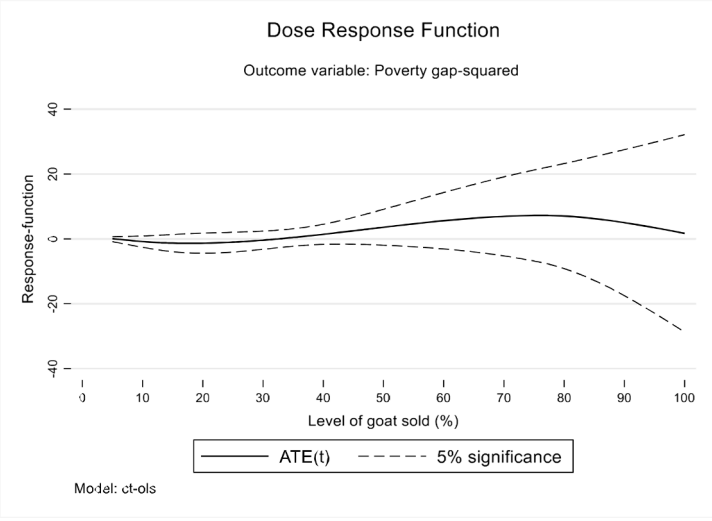


Fig. 4A. Estimates of response dose-response function on poverty severity. Note: The dose-response of the intensity of participation to the squared poverty gap is nearly zero until after an 80 percent point increase in the number of goats sold, where these poverty indices start to decrease, indicating that the intensity of poverty does not decrease with the level of goat sold, up to a very high level. Even though market participation reduces the severity of poverty, a high level of destocking needs caution as it may exert a negative impact on economic welfare for pastoralists.

5. Conclusions

Using data from the lowlands of Ethiopia, this article examined the marketing behavior of pastoralists and the impact of market participation on the welfare of pastoralists. We employed two-step bivariate models to control for the endogeneity of market participation decisions and for the selection bias that potentially emanates from unobserved characteristics of pastoralists in making these decisions. Our tests clearly showed endogeneity both in the decisions to participate and in the intensity of participation.

Pastoralists' participation in goat marketing has a significant impact on *per capita* income, poverty headcount, and poverty gap. These results reveal that pastoralists are willing to pay for better marketing infrastructure and marketing information, but this changes

Table 1A
Estimates of the decision to rear goats to predict the inverse Mill's ratio.

	Decision to rear goat
Male-headed households	−0.039
	(0.335)
Age of the head of household in years	−
	(0.010)
Household size in AE	0.183*
	(0.107)
Access to veterinary services	0.051
	(0.261)
Having a mobile phone	0.196
	(0.225)
Log of distance to market	0.137
	(0.199)
Constant	−0.131
	(0.726)
Observations	343

Note: We regress the complementary log regression to estimate the inverse Mill's ratio to control for selection bias of pastoralists' decisions to keep goats. In estimating this model, we only consider variables that can influence the decisions of pastoralists to keep goats, therefore the share of goats and the transaction costs (variable and fixed costs) are not included in the model. Market fixed effects are controlled for in the model. The household size is reported in terms of adult equivalent. AE stands for adult equivalent. Numbers in brackets are standard errors.

Table 2A
Bivariate probit estimates that include the value of the inverse Mill's ratio.

	Decision to sell Coefficient (1)	Decision to buy Coefficient (2)
Male-headed households	−0.013	−0.163
	(0.232)	(0.225)
Age of the head of household in years	−0.007	0.008
	(0.008)	(0.008)
Household size in AE	0.023	−0.104
	(0.123)	(0.108)
Share of goats (%)	0.001	0.008**
	(0.003)	(0.003)
Log of fixed cost	−0.170***	−0.169***
	(0.065)	(0.053)
Log of variable cost	0.819***	−0.737***
	(0.268)	(0.210)
Log of variable cost squared	−2.26***	2.87***
	(0.630)	(0.529)
Access to veterinary services	−0.809***	0.256
	(0.285)	(0.250)
Having a mobile phone	0.052	0.228
	(0.239)	(0.219)
Log of distance to market	−0.340*	−0.206
	(0.196)	(0.162)
IMR of goat rearing	−2.07	−1.40
	(2.31)	(2.07)
Constant	3.54**	−0.342
	(1.67)	(1.45)
Correlation of error terms	0.620***	
	(0.177)	
Observations	343	

Note: Column 2 presents the coefficients of the decision to sell model, while column 3 presents the decision to buy. To control for selection bias that can stem from the unobserved characteristics of goat rearing by pastoralists, we include the IMR value in the estimation of the market participation model. The value of IMR is post-estimation value for the complementary log-log regression. The model estimation is presented in Table 1A above. In Table 2A, the IMR estimates in both sales and purchase decisions are statistically insignificant. Market fixed effects are controlled in both estimations. The household size is reported in terms of adult equivalent. AE stands for adult equivalent. Numbers in brackets are the standard error.

when the level of TC increases beyond a threshold level of 97 % of the total variable cost. Otherwise, they are willing to pay for marketing services up to 37.12 ETB. The positive effect of transaction costs on sales shows that it is financially feasible to invest in market infrastructure through cost recovery schemes. The quadratic effect of variable TC suggests that further studies should focus on the willingness of pastoralists to pay for each market facility to determine the optimal level of the service fee. For example, a recent study by Kassie et al. (2022a) showed that smallholder farmers are willing to pay for barns for temporary holding to avoid the repetitive taxing of animals in Ethiopian livestock markets.

These results have important policy implications for reducing poverty in drought-prone areas of the country by building a climate-resilient economy. An important implication related to the participation of pastoralists in the market for both selling (both breeding and meat animals) and purchasing (only breeding animals) is differentiated products for different consumers. This could be through branding breeding and meat animals supported by the provision of reliable and timely market information. It is important to note that in circumstances where traditional livestock production is predominant, the crop-focused extension system, which is the case in Ethiopia, for example, needs to be changed to accommodate improved animal husbandry and veterinary services.

Another implication of the results is that introducing enabling policies that promote commercialization at the grassroots level can also help to make the market work for the benefit of pastoral goat producers. Typically, policies that encourage goat keepers to use sustainable ways of wealth accumulation that reduce the use of live animals as stores of value and that help them manage production and market risks better may prove to be effective in promoting commercialization among pastoralists as an important instrument to increase income and reduce poverty in drought-prone areas.

Finally, we want to highlight a couple of limitations in our study. First, we used cross-sectional data that did not allow us to look into the temporal dimensions of market participation and its impact on the wellbeing of pastoralists. Panel data could have allowed us to see the potential effect of variability and risk in goat production and marketing on pastoralists' market participation as well. Second, our study considered only goats. However, a larger study covering key livestock species that rural communities depend on would be more informative to development practitioners and policy makers.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Fig. 1A, Fig. 2A, Fig. 3A, Fig. 4A, Table 1A, Table 2A

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