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A triple-hurdle model of small-ruminant production and marketing in the highlands of Ethiopia: Implications for commercial transformation

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Abstract

This paper analyses factors that influence Ethiopian households' decisions to produce and market small ruminants using a triple-hurdle econometric model. The model integrates production, market position and volume of sales, allowing us to make inferences relating to the study population. The results are based on a dataset collected from 5 000 households and 497 rural communities in the highlands of Ethiopia. Our results show that, among other things, younger household heads, male-headed households, and households with relatively higher labour supply are more likely to engage in small-ruminant production. Flock size is an important determining factor of market participation and volume of sales. In addition, in areas where small-ruminant production is likely, market access stands out as an important determinant of household market position. Finally, our results show that the small-ruminant sub-sector is price nonresponsive, suggesting that households liquidate their animals in need of cash, not necessarily to maximise profit.

Key words: small ruminants; triple-hurdle model; smallholders; commercial transformation; Ethiopia

1. Introduction

Ethiopia is endowed with more than 55 million sheep and goats (CSA 2014), which serve as important sources of cash income and protein for rural households (Ayele *et al*. 2006). Cognisant of the importance of small ruminants to the livelihoods of the rural population, the Government of Ethiopia (GOE) has been involved in the transformation of the sub-sector to a market-oriented production system for more than a decade (MoFED 2010; NPC 2016). However, the transformation process of the subsector has been sluggish at best.

The confluence of productivity-increasing technologies and practices, and profitable market opportunities, is essential to achieve sustainable development and transformation of the agricultural sector (Minten & Barrett 2008; Omiti *et al*. 2009; Haggblade *et al*. 2010). The small-ruminant sub-sector is no exception. Small-ruminant market development is expected to generate important market

signals for smallholders to invest and actively participate in the market and improve their wellbeing (Tiffen *et al*. 1994).

The Ethiopian small-ruminant sub-sector falls short in both productivity and market participation measures. The yield per carcass weight of sheep and goats for Ethiopia in the 2012/2013 production season was estimated at 10 kg/animal and 8.5 kg/animal respectively, while the average for Africa was 14 kg/animal and 11.2 kg/animal for sheep and goats respectively (FAO 2014). Poor management practices and a lack of adequate health services also lead to high mortality and morbidity. In the 2012/2013 production season, the mortality rate was estimated at 18% and 16% for sheep and goats respectively, while the morbidity rates were estimated at 22% for sheep and 19% for goats (CSA 2014), which obviously would affect commercial off-take rates.

The sub-sector is also characterised by low commercial off-take rates. Although estimates of commercial off-take rates vary, they all show consistently low estimates (Negassa & Jabbar 2007; Gebremedhin *et al*. 2015). Recent official data show that gross and net commercial[1] off-take rates were 23% and 8% for sheep and 17% and 9% for goats respectively (CSA 2014). Off-take rates are much higher for male animals than for female animals. In the 2012/2013 production season, male sheep had a net off-take rate of 18%, compared with 4% for female sheep. Similarly, male goats had a net off-take rate of 21% compared with 7% for female goats (CSA 2014).

Ethiopian export of small ruminants also remains very low. In 2011, only about 1.1% of the sheep population and 0.1% of the goat population were exported, earning only about 16 million USD (14 million USD from sheep and two million USD from goats) (FAO 2014). These export values account for only 3.7% and 1.1% of Africa's total value of sheep and goat exports respectively.

The sluggish transformation of the traditional small ruminant sub-sector in Ethiopia calls for a rigorous empirical analysis of the factors that influence household decisions to produce and market small ruminants. Such analysis is important in order to formulate policy implications to facilitate the transformation process. Several studies have been conducted on small ruminant production and marketing practices in Ethiopia (Legesse *et al*. 2008; 2010; Kocho *et al*. 2011; Kebede *et al*. 2012; Legesse *et al*. 2013; Tadesse *et al*. 2014; 2015). However, to our knowledge, no study has integrated the production, market participation and intensity of market participation decisions of smallholders. Moreover, market participation studies on small ruminants in Ethiopia have been based mainly on small sample sizes that are limited to particular production areas, such as a district or a few districts, which makes generalising to the national level difficult.

Our analysis is based on data collected from a representative sample of 5 000 households in the four major highlands regions of Ethiopia (Tigray, Amhara, Oromia and SNNP regions), where about 75% of the country's small-ruminant population is produced. Using the dataset from a broad sample of small-ruminant producers, this paper aimed to identify factors that influence households' decisions with regard to the production, marketing and intensity of market participation using a triple-hurdle model that integrates the three decision choices.

Our results show that engagement in small-ruminant production is more likely in relatively remote areas that are further away from markets and roads, and in higher altitude areas with adequate grazing and browsing resources. Younger households with limited land resources, male-headed households, and households with a relatively higher labour supply, are also more likely to be engaged in small-ruminant production. Flock size is an important determining factor of market participation and

[1] Gross commercial off take = (sale during the year/total number of animal population during the year)*100; Net commercial off take = ((sale - purchase)/total number of animal population)*100.

volume of sales. The small-ruminant sub-sector is price nonresponsive, suggesting that households liquidate their animals in need of cash, not necessarily to maximise profit.

The paper is organised as follows. The next section presents our conceptual framework. Section 3 describes the empirical model and estimation approach. Section 4 presents the data and descriptive statistics. Section 5 presents and discusses the econometric results of the triple-hurdle model. Finally Section 6 concludes the paper and presents the implications.

2. Conceptual framework

The conceptual framework followed in this paper is based on the theoretical framework developed by Boughton *et al*. (2007) and Barrett (2008). The key features of the models are that farm households' access to markets is not uniform because households face differential transaction costs due to household- and farm-specific characteristics, as well as meso-level factors related to market infrastructures and institutions, and the degree of competition among market intermediaries. Participation in small-ruminant production and marketing therefore is modelled as a function of transaction cost factors (tc), household characteristics (hc), farm characteristics (fc), asset endowment (ae), access to services (as), community-level variables (cc), agro-ecological zones (az) and prices (p). Hence, the full triple-hurdle model is specified as follows:

$srprod$ = $srprod$ (tc, hc, fc, ae, as, cc, az, p)

$srmrpos$ = $srmrpos$ (tc, hc, fc, ae, as, cc, az, p)

$netsell$ = $netsell$ (tc, hc, fc, ae, as, cc, az, p)

$netbuy$ = $netbuy$ (tc, hc, fc, ae, as, cc, az, p)

where $srprod$ is a binary indicator of whether a household is involved in small-ruminant production, $srmrpos$ is a multinomial indicator of the market position of the household (1 = net buyer, 2 = autarkic, 3 = net seller), and $netsell$ is the net number of small ruminants sold by the household and $netbuy$ is the net number of small ruminants bought by the household. The net quantities of buying and selling are modelled separately, as the effects of the right-hand side variables on these outcomes may be different (Key *et al*. 2000). Exclusion restrictions are possible, so not all explanatory variables may be included in each model (Burke *et al*. 2015).

3. Methodology

3.1 Empirical model

Based on the conceptual framework described above, the triple-hurdle model is specified in relation to the hypotheses that small-ruminant production and market participation are determined by transaction cost factors (distance from household homestead to all-weather road ($distawr$), nearest livestock market ($distlm$)) and whether the household owns a radio ($hhradio_i$); household characteristics (age of household head ($age_i, agesq_i$), sex of household head ($hhsex_i$), education of household head[2] ($edu_{i,}$), household size ($labsup_i$) and total dependency ratio ($deprat_i$)); household assets (land ($land_i$), physical assets excluding small and large ruminants ($hasst_i$), and non-farm cash income ($cash$)); farm characteristics (small-ruminant flock size ($flksz_i, flkszsq_i$), large-ruminant herd size ($lrinflow_i$), proportion of female animals in the small-ruminant flock ($propfml_i$) and

[2] Education of household head was classified as illiterate, one to four years of schooling, five to eight years of schooling, and above eight years of schooling. We used illiterate as a base of comparison in our regression models.

number of dead small ruminants in the year ($deadanm_i$); household access to institutional services (whether household received extension advice ($srext_i$) and market information ($srmktinfo_i$) on improved small-ruminant production in the previous year, and whether the household had obtained credit during the previous year ($crdt_i$)); community-level variables (population density ($popdens$), availability of grazing land per tropical livestock unit (TLU) ($tglpltu_i$), wage rate for off-farm activities ($offmwage_i$) and agro-ecological zone of the community[3] ($azzone_i$); and district market prices (average price of small ruminants ($pricesr_i$) average price of large ruminants ($priceox_i$) and average price of butter ($pricebutr$)).

Involvement in extension and use of credit are potentially endogenous variables, since they can be related systematically to household or farm characteristics. To control for this potential endogeneity, we used lagged value of these variables.

The full triple-hurdle specification of production and market participation decisions is summarised in equations 1 to 4.

$$srprod_i = f\big(age_i, agesq_i\ hhsex_i, deprat_i, labsup_i,\ land_i, hasst_i, cash_i, lrinflow_i,\ edu_i,\ distawr_i,\ distlm_i,\ crdt_i,\ hhradio_i, popdens_i\ tglpltu_i,\ offmwage_i,\ azzone_i,\ pricesr_i, priceox_i,\ pricebutr_i, u_{srprod}\big) \quad (1)$$

$$srmrpos_i = f\big(age_i, agesq_i\ hhsex_i, deprat_i,\ land_i, hasst_i, cash_i,\ lrinflow_i, flksz_i,\ flkszsq_i,\ propfml_i, deadanm_i, edu_i, distawr_i,\ distlm_i,\ crdt_{i,}\ srext_i,\ srmktinfo_i,\ hhradio_i,\ popdens_i\ tglpltu_i,\ offmwage_i,\ azzone_i,\ pricesr_i,\ priceox_i,\ pricebutr_i,\ u_{srmrpos}\big) \quad (2)$$

$$netsell_i = f\big(age_i, agesq_i\ hhsex_i, deprat_i,\ land_i, hasst_i, cash_i,\ lrinflow_i, flksz_i,\ flkszsq_i,\ propfml_i, deadanm_i, edu_i, distawr_i,\ distlm_i,\ crdt_{i,}\ srext_i,\ popdens_i\ tglpltu_i,\ offmwage_i,\ azzone_i,\ pricesr_i,\ priceox_i,\ pricebutr_i,\ u_{srmrpos}\big) \quad (3)$$

$$netbuy_i = f\big(age_i, agesq_i\ hhsex_i, deprat_i,\ land_i, hasst_i, cash_i,\ lrinflow_i, flksz_i,\ flkszsq_i,\ propfml_i, deadanm_i, edu_i, distawr_i,\ distlm_i,\ crdt_{i,}\ srext_i,\ srmktinfo_i, hhradio_i,\ popdens_i\ tglpltu_i,\ offmwage_i,\ azzone_i,\ pricesr_i,\ priceox_i,\ pricebutr_i,\ u_{srmrpos}\big) \quad (4)$$

3.2 Estimation

Households' market participation decision can be thought of as a three-stage decision problem, where clearance from the previous stage is required for each successive stage. The first stage is the production decision (i.e. whether to engage in small-ruminant production or not), followed by the decision on market position (net buyer, autarkic, or net seller) by producers. Conditional on the decision on market position, the last stage is the decision on intensity of market participation, either as net seller or as net buyer. The flowchart in Figure 1 summarises the sequential decisions.

[3] We categorised the ten agro-ecological zones we used for sampling purposes into three broad agro-ecological zones: below 1 500 masl, above 1 500 but below 2 300 masl, and above 2 300 masl. We used the lower altitude agro-ecology as a base of comparison in our regression models.

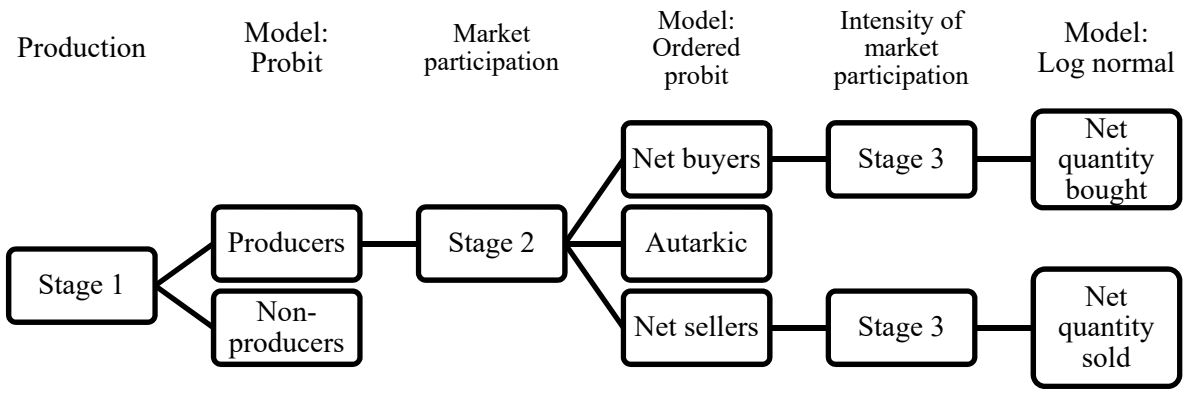

Figure 1: Graphical representation of the triple-hurdle model

The joint distribution function of $srprod, markpos, netsell$ and $netbuy$ has the following form (Burke *et al*. 2015):

$$f(srprod, markpos, netsell, netbuy|\alpha_1, \alpha_2, x_1, x_2, x_3, x_4; \gamma, \beta, \eta_s, \eta_b, \sigma_s, \sigma_b)$$

$$= [1 - \Phi\,(x_1\gamma)]^{1[srprod=0]} * \left[\Phi\,(X_1\beta)\left\{\begin{array}{c}\left[\frac{\Phi\,(\alpha_1 - x_2\beta)\,\emptyset\left(\frac{[\ln(netbuy) - x_3\eta_b]}{\sigma_b}\right)}{netbuy * \sigma_b}\right]^{1[markpos=1]} \\ [\Phi\,(\alpha_2 - x_2\beta) - \Phi\,(\alpha_1 - x_2\beta)]^{1[markpos=2]} \\ \left[\frac{\Phi\,(x_2\beta - \alpha_2)\,\emptyset\left(\frac{[\ln(netsell) - x_4\eta_s]}{\sigma_b}\right)}{netsell * \sigma_s}\right]^{1[markpos=3]}\end{array}\right\}\right]^{1[srprod=1]}$$

(5)

where $srprod, markpos, netsell$ and $netbuy$ are as defined above, $\emptyset(.)$ is the standard normal density function, $\Phi(.)$ is the standard normal cumulative distribution function, γ are the parameters on x_1 in the first stage, α_1 and α_2 are the threshold parameters similar to the standard thresholds from an ordered probit, β are the second-stage parameters on x_2, and η_s and η_b are the third-stage parameters on x_3 and x_4. Finally, $\sigma_s^2(\sigma_b^2)$ are error variance parameters to be estimated for $netsell$ $(netbuy)$.

The estimates for the parameters can be obtained by running a relevant separate regression model for each stage (Burke *et al*. 2015). Since the dependent variable in the first stage is binary, the probit model is used. For the second stage, the ordered probit model is used to estimate the parameters. Finally, the lognormal regression model is estimated to examine the intensity of market participation for net sellers.[4] All estimation is done using Stata version 14 (StataCorp 2015).

We used household labour supply as the exclusion restriction variable to estimate the second-stage model, since the availability of labour is expected to affect the decision on whether or not to produce small ruminants, but not the decision on market participation. We also used variables that measure access to market information as exclusion variables to estimate the third-stage models. Access to information can be considered as a fixed transaction-cost factor, which affects only the decision on market participation, but not the intensity of participation (Goetz 1992).

[4] Since we could not find effective identification variables for net buyers, we only present and discuss the estimation results for net sellers.

3.3 Data and sampling

The results are based on an analysis of data from a survey of 5 000 smallholder households and 497 rural *kebeles*[5] in the four highland regions of Ethiopia (Tigray, Amhara, Oromia and Southern Nations, Nationalities and Peoples (SNNP) regions). Ten zones were selected for the study, from which 62 districts were identified. The study area accounts for about 13.6% of the national area, 30% of the national sheep population, and 22.5% of the national goat population.[6] For sampling purposes, the study districts were stratified into 10 agro-ecological zones, and farm households were selected randomly based on the proportional-to-size sampling technique. Data were collected on household characteristics; farm operations; household asset ownership; farm characteristics, including land holding, flock and herd size and flock structure; access to physical and institutional infrastructure; and cash earnings of household. The survey was conducted in 2014 and referred to the 2012/2013 production season.

4. Analysis of descriptive information

Female-headed households account for less than one fifth of the total households (Table 1). Female-headed households also account for about 16% of those involved in small-ruminant production. Among net sellers, 15% are female-headed households.[7]

For those who engaged in small-ruminant production, the average flock size was about 7.85 animals, with corresponding average sizes of 9.73 for net sellers and 5.05 for net buyers. More than two-thirds of the small-ruminant stock are female animals. During the production year, a household on average lost about 10% of their flock, mainly due to diseases, which accounted for about 71% of the deaths. Other causes of small-ruminant deaths include ageing, injuries due to accidents and predators.

Land holdings were small, at about 1.38 hectare on average. The value of household physical assets, which include agricultural tools, watering cans, water pumps, wheelbarrows, animal carts, mobile phones, radios, television sets, bicycles, motorcycles and other goods, pack animals, beehives and urban property, is estimated at ETB[8] 17 660, and this increased slightly for small-ruminant producers. Based on the large standard deviation, it appears that household wealth varied quite a bit. About 43% of household heads were able to read and write, with 18%, 19% and 5% of households having formal schooling of one to four years, five to eight years and more than eight years respectively.

The nearest all-weather road and livestock market were located on average within 48.13 and 86.63 minutes of walking distance from the homestead respectively. About 19% of households took an agricultural loan during the year. Not surprisingly, about two-thirds of small-ruminant producers were located in the higher altitude areas, where the altitude ranges from 1 500 to 2 300 metres above sea level (masl) and where the annual rainfall ranges from 900 to more than 1 400 mm. In the study area, cattle (oxen) and dairy products (butter) represent potential alternative sources of income to small-ruminant production. Thus, in addition to the price of small ruminants, district market prices of butter and oxen are included in the analysis.

[5] A rural *kebele* is the lowest administrative unit in Ethiopia and comprises four to five villages.
[6] The national figures used to compute these percentages exclude the lowland non-sedentary zones of the Afar and Somali regions.
[7] Because of missing data, the final N used in the analysis is 4 618.
[8] The official exchange rate of 1 USD was equal to 20.4322 Birr on 23 February 2015.

Table 1: Distribution of explanatory variables

Explanatory variables	Total households (N = 4618)	
	Mean	Std. dev.
Household characteristics		
Age of household head *(year)*	45.32	12.18
Male-headed household *(yes=1)*	0.81	0.39
Dependency ratio	1.06	0.83
Number of working-age household members (no.)	3.18	1.48
Land owned *(ha.)*	1.38	1.36
Value of physical assets[9] (1 000 Birr)	17.66	56.12
Household non-farm income (100 Birr)	36.6	77.03
Large ruminant herd size (no.)	4.19	4.25
Small ruminant flock size (no.)	-	-
Proportion of female animals in the small ruminant flock (%)	-	-
Number of dead animals in the small ruminant flock	-	-
Education of head		
No formal education (yes = 1)	0.57	0.49
1 to 4 years (yes = 1)	0.18	0.38
5 to 8 years (yes = 1)	0.19	0.39
More than 8 years (yes = 1)	0.05	0.23
Access to services and infrastructure		
Distance to nearest all-weather road (walking minutes)	48.08	71.84
Distance to nearest livestock market (walking minutes)	86.38	62.62
Credit use (yes = 1)	0.19	0.39
Involvement in extension programme for small ruminants (yes = 1, no = 0)	-	-
Access to market information on small ruminants (yes = 1, no = 0)	-	-
Ownership of radio (yes = 1, no = 0)	0.39	0.49
Community characteristics		
Population density (persons/ha.)	3.15	2.97
Availability of communal grazing land (ha/tlu)	0.07	0.12
Wage rate (Birr/hour)	59.67	22.23
Agro-ecological zone 1 (= 1 if altitude is > 2 300 m)	0.26	0.44
Agro-ecological zone 2 (= 1 if altitude is 1 500 to 2 300 m)	0.67	0.47
Agro-ecological zone 3 (= 1 if altitude is < 1 500 m)	0.07	0.26
District prices[10]		
Small-ruminant average selling price (Birr)	723.03	122.31
Large-ruminant average selling price (1 000 Birr)	5.40	1.13
Average selling price of butter (Birr/kg)	104.92	18.83

5. Results of econometric analysis and discussion

This section first presents the estimation results for the triple-hurdle model consistent with the choice models outlined earlier. To identify the market-position model, we imposed an exclusion restriction on the household labour supply variable, which was found to be statistically significant in the production decision equation (P = 0.000), but not in market position equation (P = 0.386). Then, in order to check whether the error terms in the first and second stages were conditionally uncorrelated, a standard t-test was used on the coefficient estimate of the IMR_1. We failed to reject the null hypothesis that the coefficient estimate for IMR_1 was not different from zero (P = 0.116), and IMR_1 was excluded from the second-stage estimation of market participation.

Similarly, to identify the market-intensity model, we used access to market information variables (ownership of radio and access to small-ruminant market information), following Goetz (1992), who argues that information costs are fixed transaction costs that influence market entry, but not intensity of market participation. The Wald test of the hypothesis that the coefficients of the two variables are

[9] Excluding small and large ruminants.
[10] These are district-level averages of observed prices collected in the survey.

jointly equal to zero was rejected in the market-participation equation ($\chi 2 = 5.58$, 2 degrees of freedom, $P = 0.062$). Nevertheless, we failed to reject the same null hypothesis in the intensity of participation equation for net sellers $F(2, 1176) = 0.826$, $P = 0.442$, indicating that these two variables can be used to identify the intensity of participation equation for net sellers. Unfortunately, we could not find effective identification variables for net buyers. As a result, we only present and discuss the estimation results for net sellers.

To test whether the error terms in the second and the third stage for net sellers were uncorrelated, a standard t-test was used on IMR_s for net sellers. We failed to reject the null hypothesis that coefficient estimates for IMR_s are not statistically significantly different from zero ($P = 0.526$). Thus, IMR_s was excluded from the regression equation for net sellers.

The regression results of the first, second and third stages (for net selling only) are given in Table 2. The probit model for the production decision correctly predicts 64.7% of the categorical outcomes. The overall percentages correctly predicted by the ordered probit model of discrete market participation is about 43%. The R-squared for the log-linear model (continuous values) of net sellers is about 0.30.

We found that household age had a parabolic relationship with involvement in small-ruminant production, with the negative effect kicking in at age 44, which is about the same as the average age of the sample households. A 30-year-old (the 10^{th} percentile) farmer has a 52.3% probability of involvement in small-ruminant production compared to a 70 year old, who has a probability of 45.6%. This is probably because younger households have relatively limited access to other productive resources such as crop land (Bezu & Holden 2014), and as such would tend to depend on agricultural activities that require less land, such as small-ruminant production. Dossa *et al*. (2008) found similar result in Benin, where farmers with fewer economic options were likelier to engage in small-ruminant production.

The average probability of a given female-headed household being a small-ruminant producer was 49%, compared to 54% for an otherwise similar male-headed household. Duku *et al*. (2011) reported similar result for Ghana. Our result also reveals that access to credit has a statistically significant and positive effect on the probability of engaging in small-ruminant production. Education, as a source of power to process and interpret information, and ownership of radio, as a source of information, seem to encourage engagement in small-ruminant production. Households that keep large ruminants are also more likely to keep small ruminants, suggesting that there is complementarity in production between the two enterprises, such as in grazing behaviour (Schwartz 1983).

Community-level factors, which are outside of the control of households, are important determinants of small-ruminant production. For instance, the wage rate for off-farm employment encourages small-ruminant production and could perhaps be due to the liquidity effect of off-farm employment as a source of cash to invest in small ruminants, since small ruminants are considered as a form of saving (Dossa *et al*. 2008). However, this is a tentative explanation and requires further investigation. Population density detracts from involvement in small-ruminant production. An increase of one standard deviation in population density (three persons per hectare) decreases the probability of participating in small-ruminant production by 8.3 percentage points. The negative effect of population density on small-ruminant production may be due to its effect on land degradation, and thus the availability and productivity of grazing and browsing resources (Sibanda *et al*. 2011).

Table 2: Model estimates for production, market position and volume of sales/purchases in small-ruminant production in Ethiopia

Explanatory variables	Production (Stage 1)	Market position (Stage 2)	Net sales (Stage 3)
Household characteristics			
Age of household head (years)	0.0220** (0.025)	0.0002 (0.989)	0.0053 (0.575)
Age of household head squared (years)	-0.0002*** (0.009)	0.0000 (0.956)	-0.0000 (0.808)
Male-headed household (yes = 1, no = 0)	0.1447*** (0.007)	-0.1351 (0.848)	0.0064 (0.891)
Dependency ratio	0.0416 (0.139)	0.0189 (0.564)	0.0028 (0.900)
Number of working-age household members (no.)	0.0735*** (0.000)	–	–
Land owned (ha.)	-0.0540*** (0.002)	-0.0127 (0.543)	0.0208) (0.164)
Household wealth (1 000 Birr)	-0.0001 (0.717)	-0.0004 (0.369)	0.0000 (0.959)
Household non-farm income (100 Birr)	-0.0000 (0.966)	0.0001 (0.783)	0.0002 (0.190)
Large-ruminant herd size (no.)	0.0736*** (0.000)	-0.0188*** (0.002)	-0.0121** (0.016)
Small-ruminant flock size (no.)	–	0.1169*** (0.000)	0.0659*** (0.000)
Small-ruminant flock size squared (no.)	–	-0.0016*** (0.000)	-0.0005*** (0.000)
Proportion of female animals (%)	–	-0.0053*** (0.000)	-0.0029*** (0.001)
Number of dead animals	–	-0.0687*** (0.000)	-0.0534*** (0.000)
Head education			
1 to 4 years (yes = 1, no = 0)	0.0779 (0.154)	0.0590 (0.379)	-0.0630 (0.150)
5 to 8 years (yes = 1, no = 0)	0.0663 (0.231)	0.0703 (0.305)	-0.0271 (0.537)
More than 8 years (yes = 1, no = 0)	0.1702* (0.070)	0.0003 (0.998)	-0.0527 (0.477)
Access to services and infrastructure			
Distance to nearest all-weather road (walking minutes)	0.0007** (0.010)	0.0003 (0.323)	0.0001 (0.724)
Distance to nearest livestock market (walking minutes)	0.0005* (0.092)	-0.0010** (0.016)	0.0001 (0.634)
Credit use (yes = 1, no = 0)	0.1322*** (0.008)	0.0150 (0.805)	-0.0148 (0.696)
Involvement in extension programme (yes = 1, no = 0)	–	0.0992 (0.142)	0.0652* (0.050)
Access to market information (yes = 1, no = 0)	–	-0.0797 (0.272)	–
Ownership of radio (yes = 1, no = 0)	0.2094*** (0.000)	-0.1061** (0.039)	–
Community characteristics			
Population density (persons/ha.)	-0.0280*** (0.000)	0.0099 (0.360)	0.0116 (0.116)
Grazing land (ha/tlu)	0.3861** (0.023)	0.2210 (0.270)	0.1408 (0.311)
Wage rate (Birr/hour)	0.0042*** (0.000)	-0.0023** (0.049)	-0.0021*** (0.007)
Agro-ecological zone 1 (= 1 if altitude is > 2 300 m)	0.8405*** (0.000)	0.3528** (0.003)	0.2701*** (0.003)

Agro-ecological zone 2 (= 1 if altitude is 1 500 to 2 300 m)	0.4062*** (0.000)	0.1480 (0.199)	0.1897** (0.030)
District prices			
Small ruminant average selling price (100 Birr)	0.0002 (0.992)	0.0001 (0.996)	-0.0056 (0.740)
Large ruminant average selling price (1 000 Birr)	0.0348 (0.159)	0.0062 (0.842)	0.0744*** (0.000)
Average selling price of butter (Birr/kg)	0.0003 (0.810)	-0.0025* (0.098)	-0.0037*** (0.000)
Constant	-2.1102*** (0.000)		0.1746 (0.554)
Ancillary parameters			
Constant cut1		-1.4783*** (0.000)	
Constant cut2		0.0064 (0.987)	
IMR_b			
Percent correctly predicted/Goodness of fit	64.7%	42.9%	30.41%
Observations	4,618	2,442	1,208

Note: P-values in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1

As expected, households with smaller farmland size are more likely to be engaged in small-ruminant production, indicating that those households that face a shortage of land are likely to diversify away from land-based enterprises (Barrett *et al*. 2001). For example, an increase in land size by one standard deviation (1.36 ha) decreases the probability of engaging in small-ruminant production by about 7.2 percentage points. Despite the complementarity between large ruminants and small ruminants in production, the two enterprises seem to be substitutes as sources of cash income to the household. Households that own large cattle are more likely to be autarkic than to be net sellers, and are more likely to be net buyers than to be autarkic. Income from large ruminants may also be used to purchase small ruminants, either for consumption or as an investment. We also found a negative relationship between sales volume for a given net seller and number of large ruminants. However, the average partial effect of inflow of large ruminants on the unconditional expected value of net sales was found to be positive, at 1.8% for each additional large ruminant that joins the farmer's herd.

As expected, small-ruminant flock size and structure have strong and statistically significant effects on the market participation decision, as well as on volume of sales. A household with a larger small-ruminant flock is more likely to be autarkic than being a net buyer, and is also more likely to be a net seller than being autarkic. Wanyoike *et al*. (2015) found similar result in Northern Somalia for small ruminants and Lubungu (2016) for cattle in Zambia. Flock size does have a quadratic effect on market participation, where the negative effect sets in at 38 head of animals under the current production system. The turning-point flock size is almost five times the average flock size, showing that the current flock size is very suboptimal for promoting the market participation of households, holding other factors constant. The average producing household in our sample had a 35% probability of being a net selling household if its flock size was three (the 25th percentile), compared to a 60% probability for a flock size of 10 (the 75th percentile). Flock size also has a quadratic effect on net selling, where the turning point flock size is 68 animals. Each additional animal that joins the herd increases the volume of unconditional expected sales by 8.7%. These results strongly indicate that increasing flock size needs attention in efforts aimed at promoting the market-oriented transformation of the sector.

The results also show that the proportion of female animals in the flock is significantly negatively associated with market participation. Given that a household is engaged in small-ruminant production, a typical household with a third of its flock size (5th percentile) being female animals has a probability of about 56% of being a net seller as compared to a 48% probability if female animals account for three-quarters of the flock size (75th percentile). Similarly, among net sellers, the

proportion of female animals has a negative effect on the number of animals sold. Our result predict that, on average, a 10 percentage point increase in the proportion of female animals decreases the unconditional expected number of small ruminant sales by about 5.7%. This is because female animals are mainly kept for reproduction purpose (Wanyoike *et al*. 2015).

Animal deaths likewise exert a negative effect on the ordered market participation variable. The more animal deaths a flock suffers in a period, the more likely the producer will be autarkic over being a net buyer, and the more likely the producer will be autarkic over being a net seller. The negative effect also extends to the net sellers, where each additional animal death leads to an 8.5% decrease in the number of animals sold.

Although being further away from markets or an all-weather road favoured small-ruminant production conditional on being a producer, distance to market detracts from being a net seller over being autarkic or a net buyer. The average producing household in our sample would have a 51% probability of being a net selling household if the walking distance to the nearest livestock market is 40 minutes (25^{th} percentile), compared to a 48% probability if the livestock market were located some two hours away (75th percentile). This is probably because remote villages offer fewer opportunities for off-farm employment (Renkow *et al*. 2004) and, as such, engagement in small-ruminant production becomes an attractive livelihood-diversification strategy. We did not find a statistically significant relationship between sales volume for a given net seller and distance to a livestock market.

Involvement in a small-ruminant focused extension service increases the volume of net sales by 10%, all else being equal. This is consistent with other studies, in which extension services were linked to market orientation in developing countries (Holloway *et al*. 2000; Lerman 2004). This suggests the potential positive effect of extension services in promoting market participation by households.

We found that household decision to engage in small-ruminant production, market participation and intensity of market participation in the small-ruminant market were not affected by the price of small ruminants, suggesting that small-ruminant production is not price responsive. Small-ruminant producers may be selling animals primarily because of cash needs when market-oriented production is low (Kocho *et al*. 2011). Butter price has a negative effect on both market participation and intensity of participation, suggesting that butter is considered as a substitute source of cash income for households. We found a positive association between prices of large ruminants and volume of small-ruminant sales, perhaps because cash proceeds from the sale of small ruminants is used to invest in large livestock. In a previous study in Eastern Ethiopia, it was observed that involvement in small ruminant fattening was used as a stepping stone to large-ruminant fattening (Gebremedhin *et al*. 2012).

6. Conclusions and implications

Despite the policy and operational direction of smallholder commercialisation pursued by the Ethiopian Government for over a decade now, the small-ruminant sector has seen little transformation to date. The sluggish market-oriented transformation of the small-ruminant sector requires an empirical analysis of the factors influencing household decisions on the production and marketing of small ruminants. Such analysis would inform policymaking and development practice to facilitate the transformation process. This paper is an attempt to respond to the need for a better understanding of small-ruminant production and marketing in Ethiopia.

Using a cross-sectional dataset from 5 000 households in the highlands of Ethiopia, we estimated a triple-hurdle model to analyse the determinants of household decision to engage in small-ruminant production; household market position as net buyers, autarkic or net sellers; and the volume of sales for net sellers.

We found that small-ruminant production was preferred by younger households with limited access to land, implying that targeting the youth and the landless for market-oriented small-ruminant production may serve as a source of employment and income for such segments of the population. The grazing and browsing system of small-ruminant production and management also seems to provide better comparative advantages to male-headed households relative to female-headed households, suggesting that a change in the production practice may be needed to make female-headed households beneficiaries of the sector. The introduction and promotion of zero grazing could be one option. Access to credit encourages engagement in small-ruminant production, suggesting that the liquidity constraint is an important barrier to overcome in promoting market-oriented small-ruminant production.

Although large and small ruminants seem to be complementary in production, they tend to be substitutes as sources of cash income for the household. Small-ruminant flock size is an important determinant of market position and volume of sales, with the likelihood of being a net seller increasing continuously up to a flock size 38 animals, compared with the average flock size of 7.8. Moreover, net-selling households with larger small-ruminant flock size are more likely to sell more, showing that the current flock size is sub-optimal to promote the market-oriented small-ruminant sector. The insight gained from the effect of flock size on the marketing behaviour of households is reinforced by the negative effect of animal deaths on market position and volume of sales. These results imply that improvements in fertility, productivity and management to improve growth rates, and disease control to reduce young animal mortality, are crucial requirements in the sector.

We found that small-ruminant production in the highlands of Ethiopia is not price responsive, suggesting that small-ruminant producers may be selling animals primarily because of cash needs, while market orientation is low. The negative effect of butter prices on market position and volume of sales of small ruminants indicates that households consider the two products as substitute sources of cash income. The positive association between prices of large ruminants and volume of small-ruminant sales shows that cash proceeds from the sale of small ruminants are used to invest in large livestock.

Our results have key policy implications to promote the transformation of the small-ruminant sector into a more market-oriented system. Improvements in small-ruminant farm management practices and health services in order to increase productivity and reduce mortality stand out as priority intervention areas. Policies aimed at improving market infrastructure and marketing services are likely to increase producers' benefits and promote the market orientation of the sector. Strengthening the extension and credit services to small-ruminant producers also stands out as an important policy area.

The triple-hurdle model is an improvement over the two-stage models in that it integrates production and market-participation decisions in the analysis. Studies of the market participation behaviour of households in areas where not all households are producing the commodity can avoid biases in the estimation of marginal effects by using the triple-hurdle model. Most livestock commodities may fall into this category.

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