Fredu Nega, Mathijs, E., Deckers, J., Mitiku Haile, Nyssen, J., Tollens, E., 2012. Rural livestock asset portfolio in northern Ethiopia: a microeconomic analysis of choice and accumulation. Tropical Animal Health and Production, 44: 133–144.

Rural livestock asset portfolio in northern Ethiopia: a microeconomic analysis of choice and accumulation

Fredu Nega Tegebu · Erik Mathijs · Jozef Deckers · Mitiku Haile · Jan Nyssen · Eric Tollens

Abstract Livestock fulfill different functions. Depending on their livelihood strategies, households differ in their choice of what type of animal to keep and on accumulation of the chosen animal overtime. Using a panel data of 385 rural households in a mixed farming system in northern Ethiopia, this paper investigates the dynamic behavior of rural households' livestock holding to identify determinants of choice and accumulation of livestock overtime. Choice is analyzed for a principal animal, the animal that constituted the largest value of livestock assets a household possessed, using a multinomial logit model. Results indicate that rural households differ in their choice of what type of animal to keep. Agro-climatic conditions, sex and age of household head, presence of an adult male member in a household, and liquidity are the major factors that influence the type of principal animal households keep. Conditional on the principal animal selected, we analyzed the factors that determine the accumulation of the chosen animals by correcting for selection bias. Area of land cultivated is the most significant factor that explains the number of animals households keep. Other factors include sex of household head, diversification into nonfarm self-employment, and shocks.

Keywords Livestock asset portfolio · Choice · Accumulation · Principal animal · Northern Ethiopia

F. N. Tegebu (✉)
Department of Economics, Mekelle University,
Tigray, Ethiopia
e-mail: tfredu@yahoo.com

E. Mathijs
Division of Agricultural and Food Economics,
Catholic University of Leuven,
Celestijnenlaan 200, E box 2411,
3001 Leuven, Belgium

J. Deckers · E. Tollens
Catholic University of Leuven,
Leuven, Belgium

M. Haile
Mekelle University,
Mekelle, Tigray, Ethiopia

J. Nyssen
Department of Geography, Ghent University,
Ghent, Belgium

Introduction

Rural households in developing countries face considerable risk of fluctuating income, an inevitable consequence of engaging in rain-fed agriculture on increasingly degraded soils. In the absence or imperfection of insurance and credit markets, rural households depend heavily on assets to maintain consumption at times of income shortfall. Livestock are the largest nonland assets in rural portfolios (World Bank 2007) that are widely owned by rural households and perform multiple functions. Livestock play a vital role in the agricultural and rural economies of the developing world. Not only do they produce food directly, they are also central to farming systems used by the poor providing draught power and manure. For many smallholder farmers, livestock are often one of the most important sources of cash to buy inputs for crop production—seeds, fertilizers and pesticides, and to pay school fees, medicine, and taxes.

The role of livestock in rural communities extends significantly beyond their economic value. Most notably, livestock play a prominent role in social and cultural relationships. Loans and gifts of livestock contribute to families and communities and often play a prominent role in social and cultural relationships. Owning livestock can also bring better nutrition to some of the most vulnerable groups, including women and children (IFAD 2004). They also provide a critical reserve against emergencies and decrease vulnerability to financial shocks from ill health, crop failures, and other shocks. Households keep livestock in part because these assets have relatively high expected returns, albeit matched by high variability in returns and because livestock provide insurance against future income shock (Mutenje et al. 2008; Næss and Bårdsen 2010; Johannesen and Skonhoft 2011). In rural Ethiopia, livestock serve as (a) productive assets that allow households to be self-provisioning, (b) buffer stock for difficult times, and (c) springboard that enable some households to advance to a relative wealth status (Halderman 2004). A study of destitution in the northern highlands of Ethiopia found that the ownership of livestock was a critical factor in determining whether a household would be able to be self-provisioning or fall into poverty from which it would be extremely difficult to escape (Sharp et al. 2003).

Despite the importance of livestock, issues of livestock type choice and access have not been quite as extensively researched as issues related to land and human capital, and there is a tendency to consider them important solely for particular population subgroups (herders and pastoralists), while focusing most of the analysis of agricultural livelihoods on crop activities (Zezza et al. 2007). A wide range of studies about livestock ranging from livestock marketing (Barrett et al. 2006; Baldwin et al. 2008; Pavanello 2010) to risk management, constraints to access and stocking (De Vries et al. 2006; Davies and Bennet 2007; Mahmoud 2008) have been made mainly in pastoralist areas. Studies about livestock portfolio composition in a mixed farming system, however, are scanty. It is generally believed that the traditional cattle economy in a mixed farming system is directed mainly towards supplying draught oxen, despite a wide variety of animals that smallholder farmers keep to cater different needs.

The purpose of this paper is to investigate the dynamic behavior of rural households' livestock holding to identify determinants of choice and accumulation of livestock overtime in a mixed farming system in northern Ethiopia. We focused on oxen, breeding cattle (cow and heifer), sheep, goats, pack animals (camels, mules, and asses,) and poultry that constitute most of the value of livestock assets possessed by the sampled households.

Materials and methods

Study area

The study was conducted in the regional state of Tigray in northern Ethiopia. It is a semi-arid area characterized by sparse and highly uneven distribution of seasonal rainfall and by frequent drought. The region has a diverse topography, with an altitude that varies from about 500 m above sea level (asl) in the northeast to almost 4,000 m asl in the southwest. About 53% of the land is lowland (*kola*—less than 1,500 m asl), 39% is mid-highland (*Weinadegua*—1,500 to 2,300 m asl), and 8% is highland (*Degua*—2,300 to 3,000 m asl; Fitsum et al. 2002). The wide range of altitude governs the temperature and climatic conditions in the region.

Agriculture is the main economic stay in the region. More than 80% of the population lives in the rural areas and most depend on mixed crop-livestock subsistence agriculture. Smallholder agriculture predominates with an average land holding of less than one hectare per family. Agricultural systems in the region are characterized by traditional technology based entirely on plough cultivation of mainly cereal crops and until recently depended almost entirely on rainfall.

Besides crop production, livestock play important roles in the life of the rural households in the region. Livestock are essential for cultivating crops (draught power), transporting goods, an important source of consumption and cash income, a significant and widespread form of asset accumulation. The Central Statistical Agency of Ethiopia estimated in 2007 that farmers in Tigray have a total of 2,952,180 cattle (representing 6.85% of Ethiopia's total cattle), 973,490 sheep (4.12%), 2,771,270 goats (14.93%), 2,270 horses (0.14%), 7,250 mules (2.23%), 437,390 assess (9.72%), 34,890 camels (5.66%), 3,495,080 chickens (10.22%), and 183,800 beehives (3.76%) (CSA 2007).

Data collection

The data for this study were collected over three consecutive years—2004, 2005, and 2006—in four study *tabias*—the smallest unit of local government in the rural communities of Tigray in northern Ethiopia. Each of the *tabias* studied comprised four villages. Hence, the survey was conducted in 16 villages. A two-stage sampling design was used. The primary sampling units were *tabias*. Sample *tabias* were selected on the basis of secondary information collected from all *woredas*, the administrative unit above a *tabia*. In selecting the sample *tabias*, factors that affect socioeconomic conditions, such as nearness to market, geographical location, the availability of both rain-fed agriculture and irrigation, and size of *tabias* based on population, were considered so as to make the sampled *tabias* representative. In this category, the *tabias* of Ruba Feleg, Tsenkaniet, Arato, and Siye were selected for study. They represented the three agro-ecological zones of the region identified on the basis of altitude. Two of the tabias were in *weinadouga*, one was in *douga*, and the fourth in *kola*.

A list of households for each *tabia* separated by *kushet*—a subdivision of a *tabia* used to refer to rural village—was obtained from respective *tabia* administration. A total of 400 households were selected for the survey. Since each *tabia* was comparable in terms of population size, the sample size was distributed equally (100 households each) among each *tabia*. Once the sample size for each *tabia* was set, the allocated sample size was distributed over all *kushets* in the *tabia* in proportion to the *kushet* population. Households were picked from the list for each *kushet* using a systematic sampling procedure, i.e., households were selected from the list at a fixed interval from a random start.

Qualitative information was gathered using Participatory Rural Appraisal by a socio-economic research team in 2004. Following the qualitative survey, quantitative surveys were conducted for three consecutive years—2004, 2005, and 2006—using a questionnaire method. The survey years were such that there was shortage of rainfall (drought) in 2004 and relatively better and balanced rainfall in 2005 and 2006. A multipurpose questionnaire was used to gather information on household income, expenditure, household assets including livestock and local institutions alongside a host of other information related to production and sales. The survey questionnaire was initially administered to 400 households. An important issue for panel data is the attrition rate across rounds. Only nine households were lost in the second round and six more households in the third round. The attrition rate over the 3 years was 4%. The major reason for attrition was permanently relocating to other places after separation of households. A few households also refused to be interviewed in the second and third rounds.

Data of the three rounds were directly comparable both in terms of content and timing. A standardized questionnaire was used in all rounds and the survey was conducted in a similar season.

Modeling choice and accumulation

Econometric techniques

Choice experiments are based on the assumption that an individual *n* receives utility, *U*, from choosing an alternative *j* at time period *t* equal to $U_{njt} = U(X_{njt})$ from a finite set of *J* alternatives if and only if this alternative generates at least as much utility as any other alternative, with X_{njt} denoting a vector of attributes of *j* at time *t*. Utility is represented by two components—one portion is deterministic or observable and depends on the attributes of the alternative and the remainder is stochastic (or error term). This can be specified as:

$$U_{njt} = V_{njt} + \varepsilon_{njt} \quad , \quad \forall j, t. \tag{1}$$

where, $V_{njt} = h(X_{njt}) = \beta' x_{njt}$ is the deterministic component and ε_{njt} is a random component of the utility function.

Let P_{nit} be the probability of individual *n* choosing alternative *i* at time *t*. Assuming the random component of the utility function, $(\varepsilon_{nt})'s$ are independent and identically distributed; the multinomial logit model, as shown by McFadden (1973) and Train (2003), is given by:

$$P_{nit} = \frac{e^{\beta' x_{nit}}}{\sum_{j=1}^{J} e^{\beta' x_{njt}}} \tag{2}$$

which, gives the probability that individual *n* chooses alternative *i* at time *t* among *J* alternatives.

In dynamic aspects of behavior, current choice is influenced by past choices. Suppose for example that there is habit formation in people's choices such that they tend to stay with the alternative that they previously chose unless another alternative provides sufficiently higher utility to warrant a switch. To capture the dynamic aspects of behavior, we specify representative utility in each period to depend on observed variables from other periods. Past choice influencing current choice is captured as

$$V_{nit} = \alpha V_{ni(t-1)} + \beta x_{nit} \tag{3}$$

where, $V_{ni(t-1)} = 1$ if *n* chose *i* in period *t*-1 and 0 otherwise. With $\alpha > 0$, the utility of alternative *i* in the current period is higher if alternative *i* was consumed in the previous period. If $\alpha > 0$, the consumer obtains higher utility from not choosing the same alternative that he chose in the last period.

Using dynamic aspects of behavior (Eq. 3), the choice probabilities (Eq. 2) can be rewritten as:

$$P_{nit} = \frac{e^{\alpha V_{ni(t-1)} + \beta X_{nit}}}{\sum_{j=1}^{J} e^{\alpha V_{nj(t-1)} + \beta X_{njt}}} \tag{4}$$

In the survey, eight types of animals—oxen, cows and heifers, sheep, goats, mules, camels, asses, and chickens were identified. Since the households owning mules and camels are few in number and the purpose for which farmers keep asses, mules, and camels is the same (i.e., all pack animals are used for transportation), we combine these animals into one category which we call pack animals. Furthermore, we name cows and heifers as breeding cattle. Thus, a farmer can choose one or more animals among the six types of livestock. One way of analyzing the choice of households is to model all possible combination of animals. For the six types of livestock, the possible combinations are 63. Another way of analyzing household choice is by assuming that farmers keep a principal animal from the six animals. We define the principal animal as the one that constitutes the largest share in the value of livestock assets of a household. A household keeps most of its livestock assets in one type of animal provided the chosen animal maximizes utility of the household more than the other animals. We use the latter to analyze the choice behavior of rural households.

Conditional on the principal animal chosen, we then estimate the optimal number of animals that household n keeps as:

$$N_{njt} = x_{njt}\beta_j + u_{njt} \tag{5}$$

N_{njt} is observed only if household n chooses category j among J alternatives (six types of animals in our case) at time period t. Because the farmer may observe the error term that the researcher cannot observe, one must correct for possible selection bias. Since the farmer maximizes utility conditional on the choice of the animal type, the error in the second-stage equation may be correlated with the error in the first stage. Following Bourguignon et al. (2007), the selection bias can be corrected by including a selectivity correction term of the form

$$N_{njt} = x_{njt}\beta_j + h(P_{n1t}, \ldots, P_{nJt}) + u_{njt} \tag{6}$$

One problem with Eq. 6 is its practical implementation, for the number of parameters becomes large especially when one is having many alternatives as in multinomial logit. Thus, for practical implementation, restrictions over $h(P_{n1t}, \ldots, P_{nJt})$are required. According to Dubin and McFadden (1984), with the assumption of the following linearity condition:

$$E\left(u_j|\varepsilon_1, \ldots, \varepsilon_j\right) = \sigma_j \cdot \sum_{j=1}^{J} r_j\left(\varepsilon_j - E\left(\varepsilon_j\right)\right) \tag{7}$$

$$\text{with } \sum_{j=1}^{J} r_j = 0$$

where,

u_j error from the second stage
ε_j error from the first stage
σ_j standard error from the unconditioned second-stage regression
r_j correlation between the first stage error and second-stage error.

Eq. 6 can be estimated by least squares based on:

$$N_{njt} = x_{njt}\beta_j + \sigma_{jt} \cdot \sum_{i \neq j}^{J} r_{it}\left(\frac{P_{nit} \cdot \ln P_{nit}}{1 - P_{nit}} + \ln P_{njt}\right) + v_{njt} \tag{8}$$

where, the second term on the right hand side is the correction term and v_{njt} is the error term.

Description of variables

We estimate two sets of equations in our model. The first set of equations determines whether a farmer chooses a particular animal (among the six categories stated above) and the second estimates the accumulation of each type of animal given that a farmer has picked up a particular type of animal.

We followed McFadden's model of multinomial choice to estimate the probability that each animal is chosen. The probability of choosing each animal was assumed to be a function of household demographics (sex of household head, age of household head, age square of household head, family size, number of adult male and female household members, and number of children between 7 and 15 years of age). It is expected that demographic factors influence households' choice of the type of animal to keep. For example, male- and female-headed households are expected to have different levels of preference for oxen which are used mainly as draught animal, where mainly a man's labor is required to use the animal for farming. Similarly, households headed by young household heads and old household heads will have different preferences for the type of animal to keep given differences in experience. In the same way, the presence or absence of adult household members and children between the age of 7 and 15, who are mainly engaged in looking after herds, are expected to play a role in the selection of a principal animal.

Area of land cultivated is expected to affect households' selection of a principal animal. Area of land cultivated, as a proxy to agricultural income, is expected to release resources for the acquisition of livestock. At the same time, it is also the main source of animal feed in the form of straw collected. However, the opposite could also be the case in that households with less land to cultivate will have less agricultural income and hence use livestock income as a substitute.

Weather conditions and precipitation also affect the type of animal to keep. To capture these effects, dummies for the three agro-climatic conditions (lowland, highland, and midland) and rainfall and its square are included. Given differences in amount of investments required for different animals (some requiring bulky investment and others less), liquidity plays an important role in the type of animal a household acquires. Thus, we include access to credit, diversification to nonfarm self-employment, and nonfarm wage employment activities to capture the effect of liquidity on selection of a primary animal. Finally, the dynamic aspects of behavior entail that past choices influence current choice. To capture this inertia or habit formation, we include lagged values of the dependent variable with 1 if the household chose the animal in question in the previous period and 0 otherwise.

We estimated a second set of regressions that predict the number of animals of the chosen category a household keeps. We used demographic and other variables that explain a household's ability to accumulate livestock. Among the demographic variables, sex of household head, age of household head and its square, number of adult male and female household members, household size and dependency ratio (the ratio of children less than 15 and aged household members above 65 to adult household members) are included.

Size of farm measured by land cultivated is assumed to affect livestock accumulation in two ways: (a) area of land cultivated affects farm income, which in turn affects investment on livestock through saving; and (b) area of land cultivated also affects amount of straw collected for animal feed mainly for the dry season. Availability of animal feed determines the number as well as type of animals to keep.

Households in the study area with access to irrigation are not only able to produce more than once a year from a given plot of land, but also produce high-value cash crops mainly for the market and hence increase their liquidity. To capture this effect, we include access to irrigation.

Many farm households generate income both from farm and nonfarm activities (either through nonfarm wages employment or nonfarm self-employment). Income earned from nonfarm employment can affect investment in livestock. Hence, we include a household's diversification into nonfarm wage employment and nonfarm self-employment.

Households with access to credit can have a better chance of overcoming liquidity and indivisibility problems to invest in livestock. Thus, we include amount of loans households received from 2004 to 2006. Other variables included are market distance and shocks including crop shock, illness, and other household-specific shocks.

Results

Livestock asset portfolio

Tables 1 and 2 provide information on the prevalence and average quantity of livestock owned. Table 1 shows that few households (6% on average over the survey period) own no livestock at all and only 7% own all types of livestock. Oxen, cows, asses and chickens are owned by more than 50% of the rural households, followed by sheep and goats. Mules and camels, however, are owned by few households (not more than 2%). The percentage of households that own oxen decreased during the drought year (i.e., 2004) and rises thereafter but still remains below the pre-drought year. The percentage for the other types of livestock shows more or less a rise over the survey period.

Table 2 shows the average quantity of each type of animal owned. The table indicates that the average quantity

Table 1 Livestock ownership

Livestock category	Percentage of households owning the respective livestock in				
	2003	2004	2005	2006	Average
Oxen including bulls	71	64	66	69	68
Cow including heifer	67	70	71	71	70
Sheep	46	46	48	52	48
Goats	22	24	24	23	23
Mules[a]	–	–	2	3	2
Camels	3	3	1	2	2
Asses	56	57	60	59	58
Chickens[b]	–	70	72	82	75
All livestock	6	6	7	9	7
No livestock	6	8	5	4	6

[a] Information about mules was not collected separately for 2003 and 2004. It was mixed up with asses

[b] Data for chickens was not collected for 2003

Table 2 Average quantity of livestock holding per household

Livestock category	2003		2004		2005		2006	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Oxen including bulls	1.46	1.40	1.12	1.11	1.06	0.96	1.19	1.10
Cow including heifer	1.45	1.59	1.01	1.11	0.92	1.26	0.88	0.95
Sheep	3.95	6.36	3.27	5.09	3.31	4.82	3.73	5.26
Goats	3.43	8.92	3.12	9.18	3.26	8.75	3.74	10.58
Mules[a]	–	–	–	–	0.03	0.23	0.04	0.24
Asses	0.81	0.88	0.79	0.82	0.83	0.81	0.84	0.85
Camels	0.08	0.49	0.08	0.50	0.03	0.29	0.06	0.45
Chicken[b]	–	–	3.26	3.50	3.23	3.50	4.96	5.27

[a] Information about mules was not collected separately for 2003 and 2004. It was mixed up with asses

[b] Data for chicken was not collected for 2003

decreased for all animals except camels during the drought year (i.e., 2004). Respondents were asked if they have sold livestock during the drought year (2004) and reasons for their sales. More than 70% of the households reported that they have sold livestock in order to buy food. This supports the general view that rural households use livestock for consumption smoothing. After the drought year, changes in average quantity of the different animal types were different. The average holding for small animals (chickens, sheep, and goats) started to rise immediately after the shock year supporting the general evidence that small animals are important not only to smooth consumption at times of a shock but also to recover in the aftermath of a shock. On the other hand, the average holding of bigger animals continued to decline at least for one more year after the shock.

Next, the dispersion of livestock holding among the sample households is explored using Gini coefficient as a measure of inequality. The Gini coefficient is defined as the ratio of the area between the Lorenz curve and the uniform distribution line to the area below the uniform distribution line. The coefficient varies between 0, which reflects complete equality to 1, which indicates complete inequality.

Table 3 indicates the dispersion in distribution of livestock wealth for total livestock portfolios and each of the eight types of animals using the Gini coefficient. For comparison, inequality in distribution of land, income, and expenditure are included.

The inequality measure is comparatively stable over time with some evidence of decreasing livestock inequality. Comparing livestock inequality with land, expenditure, and income inequalities, we observe that livestock inequalities for all types of livestock were larger than inequality in land or expenditure or income. Among the livestock types, sheep, goats, and pack animals tend to be most unequally distributed with Gini coefficients well over 0.5 in all years; whereas, oxen and cows have a relatively less unequal distribution with a Gini coefficient slightly above 0.5. In general, inequality appears to increase with livestock liquidity except for chickens. More liquid livestock assets like sheep and goats are more unequally distributed than less liquid assets such as cattle. A similar result is obtained by Rogg (2006) in his analysis of asset portfolio in Ethiopia. He finds that more liquid assets like crop/food stocks and small livestock are more unequally distributed than less liquid assets such as land and large animals.

Two important points can be made from the above discussion on livestock asset portfolio. First, most households own one or more of the livestock types listed but only a few own all types of animals—an indication of differences in households' preference for the type of animal they keep. Second, although most households possess one or more of the

Table 3 Gini coefficient for consumption, income, and livestock

	2004	2005	2006
Total livestock	0.52	0.48	0.51
Oxen including bulls	0.57	0.53	0.55
Cows including heifer	0.60	0.57	0.55
Sheep	0.73	0.73	0.73
Goats	0.89	0.88	0.88
Pack animals	0.74	0.68	0.73
Camels	0.98	0.99	0.98
Mules[a]	–	0.98	0.98
Asses	0.61	0.58	0.58
Chicken	0.60	0.56	0.55
Total expenditure	0.34	0.29	0.26
Food expenditure	0.35	0.30	0.26
Nonfood expenditure	0.47	0.40	0.36
Total income	0.49	0.42	0.39
Crop income	0.58	0.46	0.45
Livestock income	0.68	0.75	0.76
Nonfarm income	0.71	0.58	0.54
Land	0.46		

[a] Information about mules was not collected separately in 2004. It was mixed up with asses.

animals; inequality in livestock holding is large. This shows significant differences in ability of households to accumulate livestock. In the next two sections, we explore why households differ in their preferences for the type of animal they keep and in their ability to accumulate the chosen animal overtime.

Selection of primary animal

Table 4 shows the results of a multinomial logit regression of the probability of choosing each of the six types of animals. Since agriculture is the main economic stay, oxen play an important role as draught animals. We prefer to compare the choice of other animals with a household that chose oxen as the primary livestock asset. Thus, the base case is a household that kept oxen as the principal animal. The test of global significance of the model verifies that the model is highly significant. Positive coefficients imply that the probability of keeping the animal increases as the corresponding variable increases. The amount of increase of the probability can be read from the odds ratio and is interpreted as the relative odds of keeping a particular animal as a principal animal relative to keeping oxen.

Female-headed households are more likely to prefer breeding cattle over oxen than their male-headed counterparts. However, the presence of an adult male member in a

Table 4 Multinomial logit selection model (base category: oxen as a principal animal; n=385)

Variable	Breeding cattle		Sheep		Goats		Pack animals		Chickens	
	Estimate	Odds ratio	Estimate	Odds ratio	Estimate	Odds ratio	Estimate	Odds ratio	Estimate	Odds ratio
Sex of HH (1=female)	0.636[d]	1.889	0.348	1.416	0.368	1.445	0.721	2.057	1.381[d]	3.978
Age of HH	0.030	1.030	0.096[b]	1.101	−0.061	0.941	0.074	1.076	0.003	1.003
Age of HH squared	−0.000	1.000	−0.001[c]	0.999	0.000	1.000	−0.001	0.999	0.000	1.000
Adult males	−0.245[c]	0.783	−0.300[b]	0.741	0.022	1.022	−0.176	0.839	−0.512[b]	0.599
Adult females	−0.073	0.929	−0.033	0.967	0.336	1.400	−0.124	0.883	−0.243	0.784
Children (7–15 years)	0.071	1.074	−0.052	0.949	0.219	1.245	0.278	1.320	−0.005	0.995
Family size	−0.057	0.945	−0.057	0.944	−0.179	0.836	0.089	1.093	−0.495[d]	0.610
Access to irrigation	0.288	1.333	0.550[b]	1.732	0.158	1.171	−1.644[c]	0.193	−0.501	0.606
Diversification (nonfarm self employment)	−0.792	0.453	−1.440	0.237	0.646	1.908	1.526	4.598	−1.240	0.289
Diversification (nonfarm wage employment)	0.448	1.565	0.383	1.467	0.616	1.852	0.831	2.297	1.571[c]	4.810
Per capita land cultivated (tsimdi)[a]	−0.273	0.761	−0.307	0.735	0.111	1.118	0.868	2.383	−0.412	0.662
Per capita land cultivated squared	0.024	1.024	0.021	1.021	−0.013	0.987	−0.126	0.882	−0.010	0.990
Rainfall	−0.014[c]	0.986	0.007	1.007	−0.024	0.977	−0.052[d]	0.949	−0.017	0.984
Rainfall squared	0.000[b]	1.000	−0.000	1.000	0.000[b]	1.000	0.000[d]	1.000	0.000	1.000
Amount of credit	0.000[b]	1.000	0.000	1.000	−0.000[c]	1.000	0.000	1.000	0.000	1.000
Lowland	0.571[b]	1.770	0.446	1.562	2.358[d]	10.568	−1.924[d]	0.146	−0.982	0.374
Highland	−0.414[b]	0.661	0.638[c]	1.892	−0.046	0.955	−0.897	0.408	0.139	1.149
Lagbreeding cattle	1.773[d]	5.891	0.514	1.673	0.477	1.611	0.157	1.171	−0.680	0.507
Lagsheep	0.729[c]	2.073	2.580[d]	13.195	−0.851	0.427	−0.330	0.719	−0.449	0.638
Laggoats	2.376[d]	10.763	1.654[c]	5.226	4.249[d]	70.066	2.699[d]	14.864	2.008[c]	7.446
Lagpack animals	0.774[b]	2.169	−0.753	0.471	0.882	2.417	3.099[d]	22.182	0.429	1.535
Lagchickens	0.490	1.633	1.840[d]	6.295	−37.761	0.000	2.760[d]	15.799	2.157[d]	8.643
Constant	3.525		−5.257		5.355		9.325[c]		4.694	

The variables with the prefix "Lag" are 1 year lag values of preference of the animal in question with 1 if the animal was chosen in the previous period and 0 otherwise

[a] Tsimdi is an area of land the can be plowed by a pair of oxen in a day and is roughly equal to one-quarter of a hectare

[b] Significant at 10%

[c] Significant at 5%

[d] Significant at 1%

Log likelihood=−1,174.1151, LR chi^2 (115)=1,020.81; $P>chi^2=0.000$; pseudo $R^2=0.3030$

household increases the probability that the household keeps oxen rather than breeding cattle as a principal animal regardless of the sex of the household head. A possible explanation for this could be the fact that in the rural areas of northern Ethiopia, farming is done using oxen and bulls as draught animals and is exclusively men's job. If a household is headed by female and if there are no adult male members to work in the field, the household is less likely to keep oxen as a principal animal. The preference is more for breeding cattle.

Agro-ecological condition is another important factor determining preference of households. Households in the lowland areas prefer to keep breeding cattle than those in the midland and highlands, where the preference is for oxen. This could be due to the fact that there is ample grazing land in the lowlands in comparison with the area in the midlands and highlands which encourages households in the former to keep more breeding cattle.

The relationship between rainfall and breeding cattle is U-shaped implying that as rainfall increases, the probability of keeping breeding cattle decreases initially but after a certain level of rainfall, the probability increases with a rise in rainfall, i.e., more and more breeding cattle are kept at high than at low levels of rainfall. Access to credit and the probability of keeping breeding cattle are positively related implying that access to credit increases the probability of keeping breeding cattle. This could be due to the fact that credit increases liquidity of households and hence lessens the indivisibility problem reflected in bulky investments such as breeding cattle.

Table 4 also reports the influence of past preferences on current behavior. This is indicated by 1 year lag value of preference for all animals except the base category—oxen. The coefficients for lagged preference for all animals except chicken are positive and significant. This implies that having previous experience of keeping breeding cattle, sheep, goats, and pack animals positively influences current preference for breeding cattle over that for oxen. For example, the positive and significant coefficient of lagged preference for breeding cattle, with an odds ratio of 5.891, indicates that for a household that had selected breeding cattle as the primary animal in the previous period, the probability of selecting breeding cattle in the current period is almost six times the probability for a household that had selected oxen in the previous period.

Sheep are strongly preferred by households in the highland area. The relationship between keeping sheep as a primary animal and age of household head is hump shaped. At an early age of a household head, the household prefers to keep sheep but at a later age the preference for sheep as a principal animal decreases. One explanation for this could be the fact that the indivisibility problem with big animals and credit constraints in the rural areas can force young households to begin their accumulation with small animals. By increasing their savings over time, they can overcome the indivisibility problem and start investing in big animals.

Since adult males engage in farming using oxen as animal power, households with adult male members have a lower chance of keeping sheep as a primary animal to keeping oxen. Access to irrigation and selection of sheep as a primary animal are positively and significantly correlated. Households with earnings from irrigation have a higher probability of keeping sheep as a principal animal.

Lagged value of sheep selection has entered with a positive coefficient implying the persistence of choice of sheep as a principal animal. Households with past preference for goats or chicken have a higher probability of selecting sheep as the principal animal in the current period when compared to the reference household. On the other hand, the coefficients of lagged preferences for big animals—breeding cattle and pack animals—are not statistically significant implying that past preferences for these animals do not significantly affect current preferences for sheep.

The probability of keeping goats is strongly correlated with agro-climatic conditions. Households in the lowland areas keep goats as the primary animal because of their ability to survive in a harsh environment. The coefficients of the lagged values of all types of animals except its own are statistically insignificant implying that past preferences for other animals do not affect current preference for goats. Although the magnitude of the impact is insignificant, access to credit has a negative effect on the probability of keeping goats as a principal animal. This means that households with access to credit do not keep goats as a principal animal as compared to keeping oxen. This could be due to the fact that access to credit lessens liquidity and indivisibility problems commonly faced when investing in big animals and hence a household with access to credit prefers to keep oxen. Put differently, the chances of keeping goats increases when households are constrained by financial capital to overcome the indivisibility problem with oxen.

Few variables explain the preference for pack animals. These animals are preferred at higher than lower precipitation. The relationship of pack animals and access to irrigation is negative implying that households with access to irrigation have a low probability of keeping pack animals compared to keeping oxen. Pack animals in the study area are mainly used for transportation such as transporting salt bars, charcoal, firewood, etc. during the slack seasons of the year. On the other hand, households with access to irrigation are highly engaged in farming even during the slack seasons. Thus, everything else equal, these households prefer to keep draught animals that support their irrigation agriculture, justifying a high preference to keep oxen rather than pack animals as a primary animal. Selection of pack animals is negatively correlated with the lowland agro-climatic conditions. The study area in the lowland agro-ecology is also the most remote in terms of distance to market. Given the purpose of pack animals, it could be noted that these animals are kept most by households closer to big markets.

Finally, chickens as principal animal are basically kept by women-headed households with small family size and those mainly engaged in relatively low paying nonfarm wage employment activities.

Livestock accumulation

Table 5 indicates the determinants of number of animals households possess conditional on the type of animal selected. Area of land cultivated is a significant factor determining the number of animals for all types of animals except goats and chickens. Area of land cultivated influences number of animals at least in two ways. First, by increasing household income it increases saving levels which in turn increases investment in livestock. Second, it affects the number of animals by affecting animal feed. One of the major constraints of livestock keeping in Tigray is the lack of adequate and quality feed. The major livestock feed sources in the region include crop residues (45%), grazing lands (35%), browse (10%) and crop aftermath (8%) derived from 3.6 million ha of cultivated land and 3.2 million ha of grazing land (BoANRD 1997; UNECA 1997). Crop residues consist of straw, stalk, stovers, sheath, and chaff. Given the high dependency on crop residue for animal feed, area of land cultivated has a positive and significant effect on the number of oxen, breeding cattle, sheep, and pack animals owned. The relationship, however, is not linear with all types of animals. It is hump-shaped for oxen and breeding cattle implying that number of oxen and breeding cattle kept increases initially but when area of land cultivated gets large, the relationship is reversed. For pack animals, the relationship is positive at large area of land.

Female headship is inversely correlated with number of animals owned. The coefficient is negative and statistically significant for oxen, breeding cattle, goats, and pack animals. This means that, everything else being equal, women-headed households own fewer animals than their male-headed counterparts.

Shocks, which include loss due to crop damage (this constitutes most of the shock value), illness, and other household-specific shocks, are inversely correlated with the number of sheep and goats owned. This means that when households' face shocks they respond mainly by dwindling down the number of their small animals (sheep and goats) as these animals are relatively liquid and there is a more ready market.

Diversification to nonfarm self-employment activities is positively and significantly correlated with number of oxen, goats, and pack animals owned. This echoes earlier findings such as the one by Woldehanna and Oskam (2001) that nonfarm self-employment activities in the region are relatively lucrative. They further pointed out that nonfarm wage employment activities in the rural areas of Tigray are less profitable and farmers enter into these activities motivated by less farm income. In line with this, we observe that households that have diversified into nonfarm wage employment own fewer livestock and in particular oxen and breeding cattle.

Family size positively and significantly influences the number of oxen and sheep households keep. Moreover, sheep accumulation is significantly influenced by age of the household head. The relationship is hump-shaped. At an early age of a household head, number of sheep owned increases; but at a later age, the relationship is reversed.

The selection bias coefficients reported in Table 5 reveal interaction among the animals. A positive value implies that the two animals are complementary. That is, if a household finds keeping one animal utility maximizing, it is more likely that the household will also choose the other animal. A negative coefficient, on the other hand, implies the opposite. The two animals are substitutes. The coefficient of selection bias for oxen "oxen-select" is positive and significant for breeding cattle and sheep accumulation. As indicated above, crop residue is the main source of animal feed and since oxen are important sources of traction power in farming, households that own other animals (breeding cattle and sheep) find it profitable to own oxen. On the other hand, goats seem to be a substitute to breeding cattle and sheep. The selection bias coefficient for goats enters with a negative sign and has a significant effect on the accumulation of breeding cattle and sheep. That is, households that own more breeding cattle or sheep find it unattractive to own goats. In the same way, households that own more goats find it unattractive to keep breeding cattle. Pack animals are complementary to oxen. Households that own more oxen find it attractive to own pack animals. The opposite, however, is not true. Finally, chickens are neither complements nor substitutes to other animals. Although the coefficient of selection bias for chickens enters with a negative sign in the accumulation regression of the other animals, nowhere is the coefficient significant. Moreover, none of the factors that affect accumulation of the other type of animals significantly influences the number of chickens owned.

Conclusions and policy implications

Using panel data of 385 rural households, we analyzed the portfolio of livestock assets in rural Tigray. Eight major

Table 5 Conditional number of animals regression (n=385)

Variables	Oxen		Breeding cattle		Sheep		Goats		Pack animals		Chicken	
	Coefficient	*t* Value	Coefficient	*t* Value	Coefficient	*t* Value	Estimate	*t* Value	Estimate	*t* Value	Estimate	*t* Value
Sex of HH (1=female)	−0.260[a]	−1.87	−0.840[c]	−2.75	−1.660	−1.31	−14.45[b]	−2.05	−1.450[c]	−2.92	−1.080	−0.69
Age of HH	0.002	0.13	−0.001	−0.01	0.430[a]	1.83	1.430	0.97	−0.080	−0.97	−0.070	−0.35
Age of HH squared	−0.000	−0.09	−0.000	−0.31	−0.005[b]	−2.08	−0.012	−0.93	0.001	1.00	0.001	0.19
Dependency ratio	−0.040	−0.53	0.070	0.37	−0.960	−1.14	3.750	0.78	0.740	1.52	0.170	0.12
Adult male	0.069	0.80	0.170	0.75	−0.170	−0.19	5.280	1.18	0.590	1.65	−1.360	−0.82
Adult female	0.080	0.85	0.350	1.46	−1.280	−1.23	5.550	1.08	1.380[c]	3.17	0.150	0.07
Family size	0.120[c]	2.61	0.060	0.48	1.500[c]	2.92	−1.060	−0.44	−0.080	−0.37	0.700	0.64
Education of HH (1=at least primary level)	0.010	0.36	−0.020	−0.36	0.510	1.46	0.440	0.20	0.040	0.24	−0.320	−0.85
Access to irrigation	0.150	1.32	0.070	0.23	−0.030	−0.03	−13.640	−1.38	0.620	0.81	−0.040	−0.01
Diversification (nonfarm self employment)	0.780[a]	1.95	0.190	0.21	7.270	1.19	60.37[b]	2.12	2.790[b]	2.23	1.570	0.37
Diversification (nonfarm wage-employment)	−0.330[a]	−1.85	−0.910[b]	−2.19	−2.430	−1.29	−5.450	−0.68	−0.600	−1.05	−1.690	−0.66
Per capita land	0.580[c]	5.76	0.650[c]	3.19	4.460[c]	2.67	7.900	1.29	−0.820	−1.14	2.100	0.69
Per capita land squared	−0.040[c]	−4.50	−0.040[c]	−2.85	−0.220	−0.58	−0.650	−0.75	0.500[b]	2.44	−0.560	−0.52
Rainfall	0.000	0.49	−0.000	−0.26	−0.002	−0.35	0.003	0.20	0.001	0.82	−0.010	−0.87
Amount of loan	0.000	1.53	−0.000	−0.14	0.000	0.69	−0.004	−0.95	−0.000	−0.12	−0.000	−0.44
Market distance (km)	−0.007	−0.67	−0.002	−0.07	−0.210	−1.64	−0.150	−0.21	−0.030	−0.54	0.210	1.06
Shock	−0.000	−0.81	−0.000	−1.62	−0.002[c]	−2.81	−0.004[a]	−1.96	−0.000	−0.95	−0.001	−0.59
Oxen—selection			1.460[b]	2.10	5.730[a]	1.76	21.150	1.32	−0.170	−0.18	4.610	1.10
Breeding cattle—selection	0.090	0.40			−1.190	−0.38	−22.260[a]	−1.69	−0.390	−0.31	−5.240	−1.03
Sheep—selection	0.300	1.33	1.000	1.59			0.930	0.03	1.430	0.55	−1.480	−0.52
Goats—selection	−0.600	−1.24	−1.390[a]	−1.77	−14.26[c]	−2.74			0.310	0.29	8.630	1.63
Pack animals—selection	0.620[a]	1.84	0.210	0.24	10.690	1.51	14.620	0.77			−6.310	−1.39
Chickens—selection	−0.570	−1.12	−1.250	−1.06	−0.820	−0.19	−14.260	−0.42	−1.130	−0.51		
Constant	0.250	0.48	2.320[a]	1.95	−2.020	−0.32	−42.100	−1.13	0.840	0.35	5.800	0.80
R^2	0.270		0.240		0.490		0.330		0.820		0.360	
Adj. R^2	0.220		0.190		0.410		0.160		0.700		0.010	

[a] Significant at 10%
[b] Significant at 5%
[c] Significant at 1%

types of livestock—oxen, breeding cattle (cow and heifer), sheep, goats, mules, camels, asses, and chickens—were identified. However, since the purpose for which mules, camels, and asses are kept in the study area is the same—all are used for transportation; these animals were grouped into one and named as pack animals. Thus, the dynamic behavior of rural households' livestock holding was analyzed for six types of animals. Choice was analyzed for a principal animal, the animal that constituted the largest value of livestock assets a household possessed, using a multinomial logit model.

Taking a household that kept oxen as a primary animal as a reference, results revealed that preference to keep small animals (goats and sheep) is mainly determined by agro-ecology. Households in the two extreme agro-ecologies—lowland and highland—prefer to keep goats and sheep respectively compared to households in the midland. Preference for breeding cattle on the other hand is directed by gender of household head and liquidity. Households headed by female and those with access to credit prefer to keep breeding cattle. The presence of an adult male in a household, however, reduces the preference. Pack animals are mainly selected by households nearer to bigger markets. Chickens on the other hand are kept by female-headed households with a small number of household members to support. In the choice dynamics, we find persistence or habitual action in choice as shown by the positive coefficient of lagged preferences for all animals.

Conditional on the principal animal selected, we have analyzed the factors that determine the accumulation of each of the six types of animals. Area of land cultivated is the most significant factor that explains number of animals (oxen, breeding cattle, sheep, and pack animals) kept. Other factors include sex of household head, diversification into nonfarm self-employment, and shocks. In connection with the importance of area of land cultivated, we also found that oxen ownership complements ownership of other animals mainly breeding cattle and sheep. On the other hand, goats are substitutes to breeding cattle and sheep.

On the basis of our findings, we recommend the following especially when intervention measures to build the livestock asset base of the rural community are sought. First, the rural community is heterogeneous in terms of choice of type of livestock to keep. Heterogeneity is determined by location and socio-economic factors. When interventions are made by distributing some species of livestock, as is done sporadically by some non-governmental organizations, heterogeneity in choice must be taken into account. The same type of livestock species may not serve the preference of all households in different areas and even for those in the same area. Second, given the shortage of adequate grazing land in Tigray, measures to develop the livestock base of the rural community must include animal feed into the package. If the current situation of heavy dependency on crop residue for animal feed continues, households without land or those without the required draught animal, or a man's labor to work in the field will have narrow chances to benefit from the sector. Women and the newly formed families are the prime households easily excludable from the benefit. The significant difference in number of animals accumulated by female- and male-headed households found in the analysis is a reflection of this.

Acknowledgments The authors are grateful to the Flemish Interuniversity Council (VLIR) for funding the research that has been carried out in the framework of the VLIR Institutional Cooperation Programme with Mekelle University.

References

Baldwin, K. L., De Veau, V., Foster, K., Marshall, M., 2008. Traits affecting household livestock marketing decisions in rural Kenya. Selected paper prepared for presentation at the American Agricultural Economics Association Annual Meeting. Orlando, FL. July 27–29.

Barrett, C.B., Bellemare, M.F., Osterloh, S.M., 2006. Household-level livestock marketing behavior among Northern Kenyan and Southern Ethiopian Pastoralists. In: J.G. McPeak and P.D. Little (eds), Pastoral livestock marketing in eastern Africa: Research policy challenges (Intermediate Technology Publications Ltd., London), 15–38.

BoANRD (Bureau of Agriculture and Natural Resource Development), 1997. Tigray Livestock Development Action Program: Executive Summary, Volume II. Mekelle. Tigray, Ethiopia.

Bourguignon, F., Fournier, M., Gurgand, M., 2007. Selection bias corrections based on the multinomial logit model: Monte Carlo comparisons, Journal of Economic Surveys 21(1), 174–205.

CSA (Central Statistical Agency of Ethiopia), 2007. The 2007 national statistics, Addis Ababa, Ethiopia.

Davies, J., Bennet, R. 2007. Livelihood adaptation to risk: Constraints and opportunities for pastoral development in Ethiopia's Afar region, Journal of Development Studies, 43 (3), 490–511.

De Vries, D.H., Leslie, P.W., McCabe, J.T., 2006, Livestock acquisitions dynamics in nomadic pastoralist herd demography: A case study among Ngisonyoka herders of south Turkana, Kenya, Human Ecology, 34 (1), 1–25.

Dubin J.A., McFadden, D.L., 1984. An econometric analysis of residential electric appliance holdings and consumption, Econometrica 52(2), 345–362.

Fitsum H., Pender, J., Nega G., 2002. Land degradation and strategies for sustainable land management in the Ethiopian highlands: Tigray region (second edition), Socioeconomic and Policy Research Working Paper 25, ILRI (International Livestock Research Institute), Nairobi, Kenya.

Halderman, M., 2004. The political economy of pro-poor livestock policy-making in Ethiopia, Pro-Poor Livestock Policy Initiative, Food and Agricultural Organization (FAO), PPLPI Working Paper No. 19.

IFAD (International Fund for Agricultural Development), 2004. Livestock services and the poor: A global initiative, (Ugo Quintily S.P.A., Rome).

Johannesen, A.B., Skonhoft, A., 2011. Livestock as insurance and social status: Evidence from reindeer herding in Norway, Environmental Resource Economics, 48(4), 679–694.
Mahmoud, H.A., 2008. Risky trade, resilient traders: Trust and livestock marketing in northern Kenya, Africa: The Journal of the International African Institute, 78 (4), 561–581.
McFadden, D.L., 1973. Conditional logit analysis of qualitative choice behavior. In: P. Zarembka (ed), Frontiers in Econometrics (Academic Press, New York), 105–142.
Mutenje, M.J., Mapiye, C., Mavunganidze, Z., Mwale, M., Muringai, V., Katsinde, C.S., Gavumende I., 2008. Livestock as a buffer against HIV and AIDS income shocks in the rural households of Zimbabwe, Development Southern Africa, 25(1), 75–82
Næss, M.W., Bårdsen, B.J., 2010. Environmental stochasticity and long-term livestock viability—herd accumulation as a risk reducing strategy, Human Ecology, 38, 3–17.
Pavanello, S., 2010. Livestock marketing in Kenya–Ethiopia border areas: A baseline study, Humanitarian Policy Group (HPG) working paper.
Rogg, C., 2006. Asset portfolios in Africa: Evidence from rural Ethiopia, UNU-WIDER, Research Paper No. 145.
Sharp, K., Devereux, S., Yared, A., 2003. Destitution in the Northern Highlands (Amhara National Regional State), final report prepared for the Institute of Development Studies, Sussex and Save the Children UK, Addis Ababa.
Train, K.E., 2003. Discrete choice methods with simulation (Cambridge University Press, New York).
UNECA (United Nations Economic Commission for Africa), 1997. Livestock development in Tigray: Forage development strategy as a major entry point towards a sustainable minimum grazing system, Part I, Sustainable Development and Environmental Rehabilitation Program (SAERP): UNECA, Addis Ababa.
Woldehanna, T., Oskam, A., 2001. Income diversification and entry barriers: Evidence from the Tigray region of northern Ethiopia, Food Policy 26(4), 351–65.
World Bank, 2007. Agriculture for development, World Development Report 2008, Washington, DC.
Zezza, A., Winters, P., Davis, B., Carletto, G., Covarrubias, K., Quinones, E., Stamoulis, K., Kafakis, T., Tasciotti, H., DiGiuseppe, S., Bonomi, G., 2007. Rural household access to assets and agrarian institutions: A cross country comparison, ESA Working Paper no. 07–177.