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

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Abstract

Livestock of different species fulfill different functions. Depending on their livelihood strategies, households differ in their choice of type of animal to keep and accumulation of the chosen animal overtime. This paper investigates the dynamic behavior of rural households' livestock holding to identify determinants of choice of type of animal households' keep and accumulation of the chosen animals using a panel data of 385 rural households in a mixed farming system in northern Ethiopia. Dynamic behavior of choice is analyzed for a principal animal, an animal that constitutes the largest value of livestock assets a household possesses, using a multinomial logit model. A household that keeps oxen as a principal animal is considered the reference household. Results indicate that households differ in choice of type of animal they keep. Agro climatic conditions, sex and age of household head, the presence or absence of male household members and liquidity are the significant factors that determine type of principal animal households keep. Conditional on the principal animal selected, we have analyzed the factors that determine the accumulation of the chosen animals by correcting for selection bias. Size of land cultivated is the most significant factor that explains the size of animals households keep. Other factors include sex of household head, diversification into non-farm self employment and shocks.

Keywords: Livestock asset portfolio, choice, accumulation, principal animal, northern Ethiopia

1. Introduction

Rural households in developing countries face considerable risk in their generation of 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 is the largest non-land asset in rural portfolios that is widely owned by rural households and performs multiple functions. It is a popular productive asset with high expected returns through offspring sale or consumption of dairy products and use in farming systems, and can be accumulated (bought) in good times and depleted (sold) in bad times for the purpose of consumption smoothing (Bundervoet, 2006).

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 (Bailey et al., 1999; Barrett et al., 2004) to risk management, constraints to access and stocking (Dercon, 1998; Desta et al., 1999; McPeak, 2005) 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 mixed farming system is directed mainly towards supplying draught oxen (Astatke & Mohammed Saleem, 1996), despite a wide variety of animals that smallholder farmers keep to cater different needs.

The purpose of this paper is to investigate dynamic behavior of rural households' livestock holding to identify the determinants of the choice of type of animals and the accumulation of the chosen animals 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.

2. Data

The data considered in this paper have been collected in three consecutive years – 2004, 2005 and 2006 – in four study tabias (the smallest unit of local government in rural communities of the present day Tigray) in northern Ethiopia. A multi-purpose questionnaire was used to gather information on household income, expenditure, off-farm income, household assets including livestock and local institutions along side a host of other information related to production and sales. The survey questionnaire was administered to 100 households randomly selected from each *tabia*. A total of 400 households were selected for the survey. An important issue for panel data is the attrition rate across rounds. Only 9 households were lost in the second round and six more households in the third round. The attrition rate over the three years is nearly 4%.

3. **Choice modeling and accumulation**

In this section, we model the choice of households for type of livestock they keep and accumulation of livestock conditional to the type of animals chosen using farmer's preferences in terms of the utility they perceive to result from various livestock types.

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 she chose in the last period.

Using dynamic aspects of behavior (equation 3), the choice probabilities (equation 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 6 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 equation (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:

$$E(u_j \mid \varepsilon_1,\ldots,\varepsilon_j) = \sigma_j \cdot \sum_{j=1}^{J} r_j(\varepsilon_j - E(\varepsilon_j)) \; with \sum_{j=1}^{J} r_j = 0 \tag{7}$$

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.

equation (6) can be estimated by least squares based on:

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

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

4. Estimation results

4.1 Selection of primary animal

Table 1 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 chooses 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.

Table 1 about here

The probability of keeping breeding cattle as a principal animal compared to keeping oxen is higher for female headed households than male headed households, but the presence of adult male member in a household reduces the probability. In the rural areas of northern Ethiopia, farming is done using oxen and bulls as draught animals and is exclusively men's job. The lack of adult male members and the fact that a household is headed by a female increases the probability of choosing breeding animals to oxen. Moreover, households who live in the low land areas keep breeding animals probably due to the fact that there is relatively large grazing land in the lowland compared to the midland and the highland, where for the latter the relationship is negative. The relationship between rainfall and breeding cattle is U-shaped implying that 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 1 also reports the influence of past preferences on current behavior. The coefficients of lagged preference for all animals are positive and significant. This implies that households with preferences for other animals in the previous period have higher probability of keeping breeding cattle in the current period. 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 6 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 the 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. Since adult males are needed to 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.

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 chickens have a higher probability of selecting sheep as the principal animal in the current period. 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 preference 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 implying that the chances of keeping goats increase 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. Selection of pack animals is negatively correlated with the two extreme agro-climatic conditions – highland and lowland, but statistically significant only with the latter. The study areas in these two agro-ecologies are also the most remote in terms of distance to market, especially the study area in the lowland. 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 non-farm wage employment activities.

4.2 Livestock accumulation

Table 2 indicates the determinants of number of animals households possess conditional on the type of animal selected. Size of land cultivated is a significant factor determining the number of animals for all types of animals except goats and chickens. Size 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). Given the high dependency on crop residue for animal feed, size 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 size of land cultivated gets large, the relationship is reversed. For pack animals, the relationship is positive at large size of land.

Table 2 about here

Sex of the household head is inversely correlated with number of animals owned. The coefficient is negative for all types of animals but it is statistically significant only for oxen, breeding cattle, goats and pack animals. This means that, everything else equal, women headed households own less animals than their male headed counterparts.

As expected, 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 each of the six principal animals owned. However, it is statistically significant only for sheep and goats. 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 readily market.

Diversification to non-farm 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 non-farm self employment activities in the region are relatively lucrative. They further pointed out that non-farm 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 diversified into non-farm wage employment own less number of livestock 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 the early age of the household head, number of sheep owned increases but at a later age, the relationship is reversed.

The selection bias coefficients reported in table 2 reveal interaction among the animals. A positive value implies that the two animals are complementary. 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 accumulation of breeding cattle and sheep. 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. 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.

5. Conclusions

Using panel data of 385 rural households, we analyzed the portfolio of livestock assets in rural Tigray. Eight major types of livestock are identified. Taking a household that keeps oxen as the primary animal as a reference, we analyzed the dynamic behavior of choice of households for a principal animal. We found 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. Size of land cultivated is the most significant factor that explains the number of most types of animals (oxen, breeding cattle, sheep and pack animals) kept. Other factors include sex of household head, diversification into non-farm self employment and shocks. In connection with the importance of size 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.

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Table 1 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***	1.889	0.348	1.416	0.368	1.445	0.721	2.057	1.381***	3.978
Age of HH	0.030	1.030	0.096*	1.101	-0.061	0.941	0.074	1.076	0.003	1.003
Age of HH squared	-0.000	1.000	-0.001**	0.999	0.000	1.000	-0.001	0.999	0.000	1.000
Adult males	-0.245**	0.783	-0.300*	0.741	0.022	1.022	-0.176	0.839	-0.512*	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 to 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***	0.610
Access to irrigation	0.288	1.333	0.550*	1.732	0.158	1.171	-1.644**	0.193	-0.501	0.606
Diversification (non-farm self employment)	-0.792	0.453	-1.440	0.237	0.646	1.908	1.526	4.598	-1.240	0.289
Diversification (non-farm wage employment)	0.448	1.565	0.383	1.467	0.616	1.852	0.831	2.297	1.571**	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**	0.986	0.007	1.007	-0.024	0.977	-0.052***	0.949	-0.017	0.984
Rainfall squared	0.000*	1.000	-0.000	1.000	0.000*	1.000	0.000***	1.000	0.000	1.000
Amount of credit	0.000*	1.000	0.000	1.000	-0.000**	1.000	0.000	1.000	0.000	1.000
Lowland	0.571*	1.770	0.446	1.562	2.358***	10.568	-1.924***	0.146	-0.982	0.374
Highland	-0.414*	0.661	0.638**	1.892	-0.046	0.955	-0.897	0.408	0.139	1.149
Lagbreeding cattle	1.773***	5.891	0.514	1.673	0.477	1.611	0.157	1.171	-0.680	0.507
Lagsheep	0.729**	2.073	2.580***	13.195	-0.851	0.427	-0.330	0.719	-0.449	0.638
Laggoats	2.376***	10.763	1.654**	5.226	4.249***	70.066	2.699***	14.864	2.008**	7.446
Lagpack animals	0.774*	2.169	-0.753	0.471	0.882	2.417	3.099***	22.182	0.429	1.535
Lagchickens	0.490	1.633	1.840***	6.295	-37.761	0.000	2.760***	15.799	2.157***	8.643
Constant	3.525		-5.257		5.355		9.325**		4.694	

Note: The variables with the prefix 'Lag' are one 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. * significant at 10%; ** significant at 5%; *** significant at 1%

Log likelihood = -1174.1151; LR chi2(115) = 1020.81; P>chi2 = 0.000; Pseudo R2 = 0.3030

Table 2 Conditional number of animals regression (n=385)

Variables	*Oxen*	*Breeding cattle*	*Sheep*	*Goats*	*Pack animals*	*Chicken*
	Estimate	*Estimate*	*Estimate*	*Estimate*	*Estimate*	*Estimate*
Sex of HH (1=female)	-0.260*	-0.840***	-1.660	-14.45**	-1.450***	-1.080
Age of HH	0.002	-0.001	0.430*	1.430	-0.080	-0.070
Age of HH squared	-0.000	-0.000	-0.005**	-0.012	0.001	0.001
Dependency ratio	-0.040	0.070	-0.960	3.750	0.740	0.170
Adult male	0.069	0.170	-0.170	5.280	0.590	-1.360
Adult female	0.080	0.350	-1.280	5.550	1.380***	0.150
Family size	0.120***	0.060	1.500***	-1.060	-0.080	0.700
Education of HH (1 = at least primary level)	0.010	-0.020	0.510	0.440	0.040	-0.320
Access to irrigation	0.150	0.070	-0.030	-13.640	0.620	-0.040
Diversification (non-farm self employment)	0.780*	0.190	7.270	60.37**	2.790**	1.570
Diversification (non-farm wage-employment)	-0.330*	-0.910**	-2.430	-5.450	-0.600	-1.690
Per capita land	0.580***	0.650***	4.460***	7.900	-0.820	2.100
Per capita land squared	-0.040***	-0.040***	-0.220	-0.650	0.500**	-0.560
Rainfall	0.000	-0.000	-0.002	0.003	0.001	-0.010
Amount of loan	0.000	-0.000	0.000	-0.004	-0.000	-0.000
Market distance (km)	-0.007	-0.002	-0.210	-0.150	-0.030	0.210
Shock	-0.000	-0.000	-0.002***	-0.004*	-0.000	-0.001
Oxen – selection		1.460**	5.730*	21.150	-0.170	4.610
Breeding cattle – selection	0.090		-1.190	-22.260*	-0.390	-5.240
Sheep – selection	0.300	1.000		0.930	1.430	-1.480
Goats – selection	-0.600	-1.390*	-14.26***		0.310	8.630
Pack animals – selection	0.620*	0.210	10.690	14.620		-6.310
Chickens – selection	-0.570	-1.250	-0.820	-14.260	-1.130	
Constant	0.250	2.320*	-2.020	-42.100	0.840	5.800
R2	0.270	0.240	0.490			
Adj. R2	0.220	0.190	0.410			

* Significant at 10%; ** significant at 5%; *** significant at 1%