Pastoral Risk and Wealth-Differentiated Mortality, Marketing and Herd Accumulation Patterns in Southern Ethiopia

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Abstract: We use herd history data collected among Borana pastoralists in southern Ethiopia to test the conventional hypothesis that pastoral risk in the semi-arid lands of sub-Saharan Africa is largely covariate. While rainfall and stocking rates together yield a clear covariate component to marketing and mortality patterns, much livestock mortality risk is household-specific. Marketing patterns also vary systematically according to household wealth. The net effect is that the steady decrease in mean household herd sizes has been borne disproportionately by households that were *ex ante* livestock poor.

I. Introduction

Extensive livestock production in the arid and semi-arid lands (ASAL) of east and southern Africa is characterized by low rates of marketed offtake, aperiodic system crashes in which half or more of the aggregate herd commonly perishes, and complex systems of interhousehold livestock gifts and loans to help rebuild herds decimated by climatic or epidemiological shocks or by raiding. The volatility of the system reflects, in part, the multiple roles livestock play in this setting, serving as a source of food (milk, blood and meat), a provider of services (manuring, traction, and transport), an object of status, and a store of wealth. Moreover, livestock help regulate the rangeland ecosystems of the east and southern African ASAL, so livestock mortality and productivity are at least partly endogenous to pastoralist husbandry decisions. Indeed, there has been considerable recent debate as to the degree to which overgrazing threatens range ecosystem health on which the pastoralists fundamentally depend, either generally or locally (Majok and Schwalbe, McPeak, Scoones et al.)

The pastoralists who inhabit the African ASAL are among the world's poorest populations. Their livestock herd comprise the bulk of their limited wealth. Conventional wisdom has long held that most of the risk faced by ASAL pastoralists is covariate, related particularly to either adverse rainfall events, excessive stocking rates, or both. There are two very important implications of the covariate risk hypothesis. First, if risk is really covariate, then indigenous capacity to cope with adverse shocks through loans and transfers is necessarily limited and sufficient and timely external assistance will be essential to pastoralists' risk bearing capacity. The more idiosyncratic the risk pastoralists face, the greater the potential role for local responses drawing on community or individual resources. Second, covariate shocks are by definition distributionally neutral. So if livestock mortality risk is covariate, then expected mortality patterns should be invariant with respect to pastoralists' *ex ante* wealth. Adverse common shocks should not disproportionately punish the poor. Yet, participatory risk assessments by pastoralists in this region reveal considerable structural heterogeneity in the hazards they deem significant (Smith et al.). The poor and the wealthy worry about distinctly different things, as do men and women. Furthermore, studies among crop producers elsewhere have shown output or income risk to be highly household-specific, or idiosyncratic, due to disease, injury, microclimatic variability, etc. (Townsend, Deaton).

If policymakers or development practitioners want to assist vulnerable pastoralists in the African ASAL, as during the present drought-related crisis in the Greater Horn of Africa, it would appear essential to have a solid understanding of the nature of pastoral risk, and the degree to which existing market and nonmarket systems serve to regulate herd sizes, preserve scarce wealth, and enable recovery from adverse shocks. The dearth of published empirical studies of pastoralist households' patterns of mortality experience or marketing behavior is thus a serious shortcoming, particularly in a region such as the Greater Horn of Africa that is of regular, acute humanitarian concern. In this paper we seek to contribute to an improved understanding of such issues.

II. Livestock, Risk and Pastoralist Behavior

ASAL households hold livestock in part because they have relatively high expected returns, albeit matched by high variability in returns, and because livestock also provide insurance against future income shocks (Desta et al., Fafchamps and Gavian, Livingstone). In pastoral systems, livestock are so fundamental to survival that herd size is typically a direct correlate of both wealth and status

(Swift). But despite the relatively attractive returns to livestock raising, pastoral herd capital was nearly always exposed to the risk of partial or complete loss (Barth). Yet, despite the general importance of livestock in these areas of Africa, livestock market integration remains poor due to the inherent difficulties involved with transporting livestock over long distances (Barrett et al., Fafchamps and Gavian) and the use of livestock as insurance to smooth consumption against income shocks appears more limited than is often appreciated (Fafchamps et al.).

There is a well-developed literature on the livestock cycles sustained by African pastoralists. In recent times, this literature was motivated by the severe drought and ensuing famine of the early 1970s, which attracted unprecedented international attention to the African continent and set off a barrage of research which sought *inter alia* to understand African pastoral systems better and thus assist in formulating more adequate responses to future crises. Livestock cycles generally run from drought, to range degradation, destocking of animals, range recovery and restocking of animals, followed by the next cycle of drought and recovery (Fafchamps, Livingstone, Swift). A key factor in these livestock cycles is the overexploitation of available pasture, often by way of overgrazing and other externalities that potentially arise from common or open access to pasture. These externalities can greatly magnify the effect of droughts on livestock (Coppock, de Leeuw and Tothill, Fafchamps, Sanford, Turton). Thus much of the pastoral risk associated with livestock cycles is conventionally considered covariate in the sense that it is collectively experienced. Livestock losses during these cycles can be massive (commonly, with 50-80% losses for cattle and 30% for sheep and goats), and these cycles strongly determine the effectiveness of risk-coping strategies among the ASAL poor, whose access to financial savings, credit, and insurance is extremely limited.

In SSA, the terms of trade of livestock products (i.e., meat and milk) for agricultural products such as grains is generally quite favorable for pastoralists (Swift, Cossins and Upton). Many commentators have seized on this observation to argue that livestock can and do play an important role in providing self-insurance to African pastoralists (Binswanger and McIntire, Swift, Swinton, Turton). But during times of drought, the terms of trade for livestock products often collapses with the herd, especially when the proximate cause is drought that also reduces grain supply. The combination of poor market integration and drought can thereby impede the self-insurance role of livestock if falling real livestock prices induce households to retain livestock despite reduced income and consumption, depressed animal productivity, and increased chance of mortality if the animals remain locally (Cossins and Upton 1988, Fafchamps et al.). ASAL pastoralists appear surprisingly autarkic in the face of variable returns and unstable consumption.

These indirect and compound factors may signal a potentially important idiosyncratic component to pastoral risk. Small herds may not be able to cope as well as large herds when faced with tough times (Tacher). If poor households tend to have fewer consumption options and are therefore forced to rely disproportionately on their livestock for milk (and/or blood), their livestock are likely to become weaker and exposed to greater risks during drought as explained above. Upton observes that Ethiopian households with large herds milk 35-45% of their cows, while those with small herds milk 65-75%, which in times of stress adversely impacts calf growth and survival. Sieff reports similar findings from Tanzania. To the extent that households differ in their ability to mitigate and treat disease, through veterinary supplies for example, the risks posed by livestock disease may also be significantly idiosyncratic (Sieff). Differential access to herding labor and to livestock markets may also introduce a substantial idiosyncratic component to pastoral risk. Thus even if covariate climatic events and aggregate stocking rates on common property rangelands are the primary sources of livestock cycles, as long as households differ in their ability to cope with or mitigate these risks there are likely to be dramatic differences in the damage sustained across pastoral households.

This may have significant effects on wealth distributions among ASAL pastoralists. Some argue that the poor suffer disproportionately high livestock mortality rates, for some of the reasons mentioned in the preceding paragraph (Sieff) or that rich pastoralists have other options for smoothing consumption in the face of identical livestock mortality experiences, and thus sell livestock less frequently than do poor pastoralists (Upton). Others conjecture that in spatially segmented markets the rich may speculate on fluctuating livestock prices (Fafchamps), or that the poor haven't sufficient liquidity to accumulate high-risk, high-return assets such as livestock (Dercon). The implication under any of these explanations is that rich households seem to accumulate livestock while poorer households decumulate animals and exit the pastoral system over time. In so far as livestock mortality risk is indeed idiosyncratically experienced by pastoralists, one would therefore expect this to manifest itself in long-term accumulation patterns that appear dependent on ex ante household wealth. With pastoral systems and their participants increasingly stressed due to loss of spatial refugia to town growth, increased area under cultivation, gazetting of parks and protected areas, and violence (Coppock, Desta), the potentially wealth-differentiated nature of livestock mortality and marketing patterns is of considerable immediate interest.

III. Data

Desta compiled 17-year (1980-97) cattle herd histories for a set of 55 different randomly selected households drawn from four community (Arero, Mega, Negelle and Yabello) on the Borana Plateau in southern Ethiopia. Because 16 of the sample households were formed within the 17 year period, this is an uneven panel of data, with 833 total observations. The 1980-1997 period includes two different, major droughts during which large numbers of livestock perished. The data include annual observations on mortality, marketing, gift and loan, slaughtering, and calving, as well as on labor availability, climatic conditions, and aggregate local stocking rates. Changes in cattle herds register prominently among ASAL pastoralists, thus herd history data among these peoples typically prove more reliable than even shorter recall data on consumption, crop production, income, or labor patterns (Turner).

The importance of cattle mortality as a lost opportunity in this setting is perhaps best reflected by Desta estimates that asset losses due to cattle mortality in the Borana community over the 17 year period total about $300 million, easily an order of magnitude greater than external transfers into these communities. Development agencies working in the region seek to reduce losses due to livestock mortality, through improved husbandry and range management, diversification into less risky assets, improved livestock marketing systems, etc. But appropriate targeting of interventions depends fundamentally on an improved understanding of the source of risk and pastoralists' established response to shocks, perhaps especially among the poor. This paper is part of a much broader project aimed at shedding light on these issues.

The Borana system depends heavily on cattle, managing their livestock in two sub-herds, a wet or *warra* herd and a dry or *fora* herd.[1] The *warra* herd consists of milking cows and calves and is generally kept near the settlement, while the *fora* herd consists of immature cattle and dry cows and is therefore more mobile and better adapted to long-range migration in search of dry-season grazing. Milk from the *warra* herd provides the mainstay of the Borana diet and most cash incomes are based on cattle sales. As in other pastoralist systems, the Borana rely on exchanging cattle for grain for their survival. And like most ASAL pastoralist systems, the Borana face prominent weather-related risks and poorly integrated livestock markets. Disease is somewhat less severe a problem on the Borana Plateau than elsewhere in the east African ASAL, with most livestock mortality attributable to poor nutrition and dehydration.

The aggregate data reveal precisely the patterns of interest. Household average herd sizes have varied significantly over time, exhibiting both pronounced cycles and a clear downward trend (Figure 1). Mean household herd size was 128 cattle in 1980-81 but only 91 in 1996-97, having dipped as low as 72 head in the drought year of 1992-93.[2] The steady decrease in herd sizes is

[1] This background paragraph draws heavily on Coppock, Cossins and Upton (1987, 1988a, and 1988b), and Desta.
[2] This probably understates the degradation in mean herd sizes since these data derive from a 1997 survey of pastoral households and any herding households as of 1980-81 who exited the system prior to 1997 are therefore omitted.

reflected by a steady leftward shift of the cumulative frequency distribution for household herd sizes, with the five-year distribution for 1980-84 first-order dominating that for 1986-90, which in turn first-order dominates the 1992-96 distribution. It is clear that Borana pastoralists are getting steadily poorer in livestock terms. And both culturally and economically, reduced livestock wealth means diminished status and living standards among these pastoral peoples. The increased stress in this system is readily apparent.

Marketed offtake is extraordinarily limited, with gross sales peaking at just 3.3 percent of beginning period herd size. Average household gross cattle sales have a simple bivariate correlation coefficient of 0.578 with average household cattle mortality, indicating that sales do respond to stress. Nonetheless, mortality, not marketing, is the dominant regulator of herd sizes, with mortality greater than net sales every one of the seventeen years, and hitting 25-35 percent of the aggregate herd in drought years (Figure 3). Moreover, the correlation coefficient between livestock prices and mortality in these data are modestly negative, -0.05, -0.04, and –0.02 for calves, bulls, and cows, respectively. The Borana pastoralists do not appear to enjoy the empirical regularity of income-stabilizing negative covariance between output and price commonly found in the context of crop agriculture, a feature that seems attributable to both livestock's primary role as an asset whose productivity affects its price, and to the poor state of livestock markets in the African ASAL (Barrett et al.).

IV. Livestock Mortality Experience Among The Borana

The data permit investigation of whether livestock mortality is attributable to commonly experienced shocks associated with rainfall and stocking rates, whether individual herd size affects one's experience of those covariate phenomena, and whether there are significant idiosyncratic, or household-specific, factors that account for mortality experience. Might seemingly distributionally-neutral shocks (e.g., low rainfall) have wealth-differentiated mortality effects? These questions motivate the econometric work reported in this section.

We estimate a few variants of a single basic mortality model taking as its dependent variable the total cattle mortality experience of household i in location j[3] over the course of year t (M_{ijt}) and a vector of independent variables as follows:

(1)
$$M_{ijt} = \beta_0 + \beta_1 M_{jt} + \sum_{r=1}^{2} \beta_{2r} R_{rjt} + \sum_{r=1}^{3} \beta_{3r} H_{jt} R_{rjt} + \sum_{r=1}^{3} \beta_{4r} H_{ijt} R_{rjt} + \sum_{r=1}^{3} \beta_{5r} H_{ijt}^{2} R_{rjt}$$
$$+ \sum_{b=1}^{2} \beta_{6b} L_{bijt} + \sum_{r=1}^{2} \sum_{b=1}^{2} \beta_{7rb} R_{rjt} L_{bijt} + \boldsymbol{\theta} \cdot \mathbf{V} + \varepsilon_{ijt}$$

Let M_{jt} represent the average mortality experience for all households in location j over period t excluding household i. If mortality risk is perfectly covariate, then β_1 should be positive and there should be zero effect from household-specific variables such as beginning period herd size, H_{ijt}, household labor availability, L_{ijt},[4] and time-invariant household-specific dummy variables, **V,** that control for relevant unobserved household characteristics such as animal husbandry skills and pastoral experience. Failure to reject this strong null hypothesis would signal that mortality experience is uniform across households within a given community and year.

One potential problem with the above model is that M_{jt} may be simultaneously determined with M_{ijt}. An alternative test of the covariate risk hypothesis substitutes exogenous beginning period stocking rates, captured by H_{jt}, the herd size for location j at time t, excluding household i, and R_{jt}, a rainfall dummy variable,[5] for M_{jt}:

(2)
$$M_{ijt} = \beta_0 + \beta_1 M_{jt} + \sum_{r=1}^{2} \beta_{2r} R_{rjt} + \sum_{r=1}^{3} \beta_{3r} H_{jt} R_{rjt} + \sum_{r=1}^{3} \beta_{4r} H_{ijt} R_{rjt} + \sum_{r=1}^{3} \beta_{5r} H_{ijt}^{2} R_{rjt}$$
$$+ \sum_{b=1}^{2} \beta_{6b} L_{bijt} + \sum_{r=1}^{2} \sum_{b=1}^{2} \beta_{7rb} R_{rjt} L_{bijt} + \boldsymbol{\theta} \cdot \mathbf{V} + \varepsilon_{ijt}$$

In recent years, the range science literature has vigorously debated the relative importance of stochastic rainfall and herd stocking rates in driving mortality patterns, implicitly contending over whether overgrazing

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[3] The locations we use are the four distinct study centers surveyed by Desta: Arero, Mega, Negelle, and Yabello.
[4] Labor availability was recorded as low, moderate, or high, so we use two dummy variables here to capture the low (1) and high (2) labor availability states.

is a problem in the ASAL or whether climatic shocks regulate herd size before resource availability per animal become a binding constraint (Majok and Schwalbe, McPeak, Scoones et al.). The estimated relationships between stocking rates and rainfall can perhaps contribute to that debate. Of more direct relevance to the questions motivating this paper, a test of the joint exclusionary restriction on H_{jt} and R_{rjt} and their interaction terms -- i.e., that these factors jointly have zero effect on mortality -- is a weak form test of the no covariate risk null hypothesis, in contrast to the previous, strong form test. The complementary joint exclusionary restriction on the idiosyncratic variables is likewise a test of the no idiosyncratic risk null hypothesis. Rejection of both joint null hypotheses, the result we consistently obtain, indicates that livestock mortality risk is attributable to both covariate and idiosyncratic factors. So widespread drought or high stocking densities may induce greater mean mortality, but not all will share equally in this adversity.

The presence and importance of stocking externalities can likewise be tested using the specification in equations (1) or (2). If mortality increases at less than a one-for-one rate with *ex ante* herd size, then a household's own expected end-of-period wealth is increasing in its herd size, as one would expect. But if livestock mortality rate is also increasing in the size of the overall local herd, H_{jt}, then each household's increased herd size indeed imposes a negative externality on the other households in the community, presumably through competition for forage and water, or increased risk of disease transmission or cattle raiding. So by testing the hypothesis the null hypothesis $\beta_{3r}= \beta_{5r}=0$ and $\beta_{4r}=1$ versus the alternate $\beta_{3r}>0$ and $\beta_{4r}<1$, $\beta_{5r}<0$, one can determine whether stocking externalities exist.

Specifications (1) and (2) use M_{ijt} as the dependent variable, expressing mortality in terms of the number of deceased livestock. It may be more appropriate to let the dependent variable be the mortality rate, expressed as a proportion of beginning period herd size, m_{ijt} M_{ijt}/H_{ijt}, and substituting m_{jt} M_{jt}/H_{jt} for M_{jt} on the righthand side of (1). Call this revised specification (1´). This modification addresses situations such as when a relatively poor pastoralist owning only 10 cattle loses 5 during the year while a wealthier pastoralist with 100 cattle also loses 5. Specification (1) would find no relation between herd size and mortality, while that of (1´) would show a negative relation between mortality rates and herd size. With the mortality being estimated in proportions, the strong covariate risk test uses the null hypothesis H_0: $\beta_1=1$ and

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[5] These rainfall dummy variables represent high (1), low (2) and average (3) rainfall.

$\beta_i = 0\ \forall\ i \neq 1$ versus the alternative H_A: $\beta_1 < 1$, or $\beta_i \neq 0$. We likewise modify specification (2) by substituting m_{ijt} for M_{ijt}, and label the resulting model (2´).

The final refinement we offer focuses the mortality experience on calves. Calves are the highest return and highest risk component of a herd, and past researchers have found that calf mortality appears negatively correlated with wealth even when total mortality is not (Cossins and Upton 1988, Sieff). So we reestimate the four models, (1), (2), (1´), and (2´) using the regressand calf mortality, CM_{ijt}, or calf mortality rates, cm_{ijt} CM_{ijt}/C_{ijt},[6] and CM_{ijt} and cm_{ijt} as regressors, as appropriate.

Since mortality experience is nonnegative and bounded from above at one's *ex ante* herd size, the models estimated here are subject to censoring. Specifications (1) and (2), for both total mortality and calf mortality, are censored at the interval boundaries $[0,H_{ijt}]$, while specifications (1´) and (2´) for total or calf mortality rates range over the [0,1] interval. So we estimate these specifications using doubly-censored regression methods (Greene).

Table 1 presents the estimates of the four models for total cattle mortality. There is indeed a positive and statistically significant association between household and community livestock mortality, although it is far from the one-for-one relation imposed by the strong form test of exclusively covariate risk. A one percent increase in the community mortality rate implies an expected increase in a household's mortality rate of only about half of one percent. In the models that use rainfall dummies and cluster herd sizes instead of community mortality experience, thereby obviating potential simultaneity bias, mortality rates fall significantly, by 22 and 28 percent for high and moderate rainfall years, respectively, relative to low rainfall years. We find no evidence that community stocking rates affect mortality, either independently or jointly with rainfall. Perhaps surprisingly, we find no evidence in support of the hypothesis of negative stocking externalities. This likely reflects the facts that rainfall on the Borana Plateau, averaging 600-700 millimeters annually, is relatively high for the east African ASAL, that the Borana have well-established

[6] C_{ijt} is the number of calves born to household i in location j at time t

systems of deep wells and cooperative labor arrangements for bringing up water from those wells in the dry season for all herds, and that range degradation has been minimal in the region, although bush encroachment by woody species is increasingly a problem (Coppock). The likelihood ratio test statistic equals ___, with a p-value of ___ for the exclusionary restriction that the five rainfall dummy, cluster herd size, and cluster herd size-rainfall interaction terms jointly have zero effect. [Travis: please fill in these blanks.] Common shocks, seemingly especially rainfall shocks, plainly matter to the mortality experience of pastoral households on the Borana plateau.

Nonetheless, mortality risk plainly has a significant idiosyncratic component as well. Own herd size is positively and statistically significantly related to own mortality experience. This may pick up a more localized stocking rate problem or it could reflect greater susceptibility to animal disease. But both models (1') and (2') indicate that the addition of about 40 head of cattle, equivalent to an upward shift of about a tercile of the herd size distribution, increases one's expected mortality rate by ten percent in a low rainfall year. Higher rainfall mitigates the expected effects of herd size on mortality. So larger *ex ante* herds thus imply larger *ex post* herds. The best way to survive a general or local crisis is to have a larger herd, even though one then expects to lose more animals and even a greater share of one's herd. That finding is also reflected in the statistically significantly sub-unit point estimate (0.52) relating own herd size to own mortality. Our crude dummy variable measures of household labor availability are effectively unrelated to mortality experience, although it is important to keep in mind that the household dummy variables pick up time-invariant labor characteristics such as husbandry skills, education level, etc. that perhaps play a role in conditioning the relationship between labor availability and mortality rates. [Travis: we need a likelihood ratio test of the exclusionary restriction that the household dummies have no effect. I suspect we can overwhelmingly reject that null, but please conduct the test and generate the LR test statistic and p-value.]

Calf mortality (Table 2) appears far less responsive to covariate shocks than does total herd mortality, with no single covariate term statistically significantly different from zero in model (1) [joint significance via LR test?]. Calf mortality rates are nonetheless significantly decreasing in rainfall. Calf mortality, in both level and rate, also increases significantly with own herd size, with the effect dampened in higher rainfall years.

Together, these results suggest both covariate and idiosyncratic mortality risk are at play among Borana pastoralists, with idiosyncratic risk somewhat more prominent in driving calf mortality. Generalized drought seems the primary source of covariate risk, as has been vividly reflected on international news broadcasts during both the current drought in this region and several others over the past twenty years. Yet there remains considerable inter-household variation in livestock mortality experience associated with *ex ante* household herd size and unobserved individual household characteristics. So the challenge of pastoral risk management goes far beyond responding to climatic variation.

V. Livestock Marketing Among the Borana

As Figure 3 showed, mortality is the dominant regulator of Borana herd sizes. But marketing patterns matter as well since livestock sales allow a pastoralist to smooth consumption in the wake of an adverse mortality or productivity shock, or to mitigate mortality risk by selling animals before they perish, and livestock purchases are essential for long-term recovery from an adverse mortality shock. In part for these reasons, development agencies in the region are increasingly emphasizing the necessity of improving the livestock marketing infrastructure and increasing offtake rates. Marketing may therefore become more important in the future. This section therefore explores cattle sales and purchase patterns among the Borana.

There is considerable anecdotal and ethnographic evidence on pastoralist livestock marketing behavior (e.g., Kerven, Little), but remarkably little econometric work. The literature reports distress sales by the poor to the rich in times of stress, suggesting that adverse common shocks lead to increasing concentration of the aggregate herd in the hands of a few households. It also suggests that the wealthy have greater liquid, non-livestock assets and so are less likely to sell animals to resolve liquidity problems and have greater capacity to purchase animals. Such claims point to several testable hypotheses.

The model specifications employed are similar in spirit to the mortality models already reported. We use six distinct dependent variables: gross sales (S), gross purchases (P) and net sales, NS S-P, all in numbers of cattle, and the equivalent flows as a proportion of beginning period herd size, s, p, and ns. As with the mortality models, these are all variants of the same basic model, specified as follows:

(3)
$$S_{ijt} = \beta_0 + \beta_1 M_{ijt} + \sum_{r=1}^{2} \beta_{2r} R_{rjt} + \sum_{r=1}^{3} \beta_{3r} H_{jt} R_{rjt} + \sum_{r=1}^{3} \beta_{4r} H_{ijt} R_{rjt} + \sum_{r=1}^{3} \beta_{5r} H_{ijt}{}^{2} R_{rjt}$$
$$+ \sum_{b=1}^{2} \beta_{6b} L_{bjt} + \sum_{r=1}^{2} \sum_{b=1}^{2} \beta_{7rb} R_{rjt} L_{bjt} + \beta_8 P_{ijt} + \boldsymbol{\theta} \cdot \mathbf{V} + \varepsilon_{ijt}$$

Like the mortality models' dependent variables, livestock sales and purchases are censored. S and P are left censored at zero, while s and p are interval censored at zero and one.

This specification allows for testing of several hypotheses of interest. First, the prevalence of distress sales can be inferred by testing the hypothesis H_0: $\beta_1=0$ in the case of gross or net sales, reflecting sales activity associated with periods of higher livestock mortality. If we reject the null in favor of the alternate hypothesis H_A:$\beta_1>0$, it would seem that pastoralists sell more livestock during periods of greater mortality, perhaps signaling that livestock sales represent a coping strategy for pastoralists whose asset stock is depleted and who need more liquid assets to deal with reduced livestock productivity (i.e., to purchase grain when cows are drying up). By contrast, rejecting the null in favor of H_A:$\beta_1<0$ could be evidence of either sales as a mitigating strategy whereby pastoralists reduce their mortality experience by selling off their animals or of mortality supplanting sales of animals (i.e., they die before they can be delivered to market). This signals the potential endogeneity problem that exists if a pastoralist endogenously determines some portion of their mortality experience by opting to sell or hold their livestock. We therefore instrument for M_{ijt}. [Travis: need to explain instruments and first-stage regression performance here.]

The own herd size parameters, β_{4r} and β_{5r}, reflect switching regression estimates for the effect of herd size on sales under different rainfall regimes. These parameters signal any wealth-differentiated sales behavior. Especially important to questions of wealth dynamics in pastoralist economies, if β_{41}(high rain regime)>β_{43}(average rain regime)>β_{42}(low rain regime), wealthy pastoralists may be behaving counter-cyclically, selling more livestock during high rainfall years when demand and prices are high than when the market is saturated with distress sales during low rainfall years. As in the mortality models, own herd size enters in quadratic form to pick up any nonlinear relationships, presumably with sales increasing in own herd size, but at a decreasing rate. The labor availability parameters, β_{6b} and β_{7r}, will indicate whether households appear to maintain an optimal livestock-labor ratio, in which case β_{61}(high labor)>β_{62}(low labor). The β_{7r} parameters should indicate whether this ratio changes under different rainfall regimes. Finally, β_8 will indicate the correlation between gross purchases and gross sales.

Estimation results for the marketing models appear in Table 3. Marketing patterns as a share of herd size do not vary with mortality rates. The positive sign and statistical significance of the $\beta_1$parameter estimates in the gross and net sales models hints at some distress sale behavior, but the magnitudes of the point estimates are extremely small. The magnitude of the negative and statistically significant gross purchases parameter estimate suggest pastoralists may be quicker to suspend purchases than they are to sell off their livestock in poor years, although both effects are quite modest. On balance, livestock marketing by the Borana appears effectively nonresponsive to their mortality experience, a pattern that accords well with past findings that pastoralists seem to sell fewer livestock during tough years than would be expected if they used their herds to smooth consumption (Coppock; Fafchamps; Fafchamps, Udry and Czukas).

The relationship between marketing behavior and own herd size suggests that pastoralists tend to have higher net sales in high rainfall years. In particular, gross sales are increasing faster in own herd size in good rainfall years, suggesting larger herders indeed take advantage of the higher prices more productive animals fetch on the market during favorable years. The proportions models suggest that this relationship between own herd size and both gross and net sales is negative (i.e., small herd pastoralists sell proportionately more across all rainfall regimes), while that between herd size and gross purchases is positive for at least the average rainfall regime (i.e., large herd pastoralists purchase proportionately more). Such a marketing dynamic, in which the big get bigger through negative net sales, reinforces the herd size-mortality relation identified in the preceding section, in which larger *ex ante* herds have a larger expected *ex post* size in spite of somewhat higher expected mortality rates. This raises natural questions as to whether marketing and mortality dynamics are concentrating herd ownership in the hands of the relatively wealthy on the Borana Plateau.

VI. Wealth-Differentiated Livestock Accumulation Patterns

The nature of herd accumulation dynamics can be addressed using transition matrices depicting a household's herd size at time t and then the same household's herd size at time t+q, where q represents the interval, measured in years. We look at year-on-year transitions (q=1), five year transitions (q=5), and ten year transitions (q=10). We divide the sample into quartiles derived by pooling all the households and years together. Quartile one is then households with less than 19 cattle, quartile two comprises those with at least 19 but less than 34 animals, households with 34-74 head of livestock are in the third quartile, while those with 74 or more fall into the largest quartile. The two larger boundaries almost precisely match the tercile splits among the households with 1980/81 data, while the lower boundary coincides with the lowest decile in the 1980/81 data. This too signals how household herd sizes have declined over the 17 year period under study. A herd of twenty cattle put one in the lowest ten percent of these households in 1980/81, but only in the lower 40 percent by 1997. Starkly put, there appears to be a convergence on collapse.

Table 5 shows three transition matrices, at one, five, and ten year frequencies as one works from the top panel to the bottom. A feature that immediately jumps out is that those households finding themselves with a small herd, one in the lowest aggregate quartile, are trapped. Lowest quartile herders face an almost ninety percent probability (0.207/0.236=0.88) of remaining trapped in that quartile the next year and a greater than ninety percent probability (0.143/0.155=0.92) of not escaping the lowest quartile in ten years.

By contrast, those households in the upper quartile seem reasonably safe. Less than three percent of them collapse into the bottom two quartiles the next year, and only nine percent fall into the bottom two quartiles after ten years. Accumulating a large herd indeed appears to offer reasonable insurance of surviving on the range. Increased mortality rates do not offset the net sales and births into the herd, at least not sufficiently to induce a sharp fall in herd size.

The herd size transitions of Table 5 are graphically illustrated in Figures 4 and 5, which also clearly shows the trend to smaller herd sizes. A simple regression using the 38 households for which we have a full 17 years' data shows that each one percent increase in herd size at time t yields an expected 0.97 percent increase in herd size at time t+10.[7] And this overstates the degree to which herd sizes persist, given attrition bias in the sample caused by the exit from the sample frame of those households that were herders in 1980 but lost their herds permanently by the time of the 1997 survey. When one estimates the same regression off the lowest quartile of the 1980 herds, the unsustainability of small herds becomes readily apparent. Now the simple univariate relation is $\ln(H_{t+10}) = -4.33 + 2.35\ln(H_t)$,[8] implying that herds of less than six head are not expected to exist ten

[7] The simple univariate regression result is $\ln(H_{t+10}) = -0.31 + 0.97\ln(H_t)$, where the t-statistic on the intercept estimate equals –0.71 and that on the slope estimate equals 9.16.
[8] The t-statistics on the intercept and slope are –5.34 and 7.24, respectively.

years later, and none of that cohort (for which maximum herd size was 24 cattle) would have been expected to maintain their herd size, with the larger among them shrinking the least.

Conclusion

In this paper, we have exploited an uncommonly long panel of herd history data among the Borana pastoralists of southern Ethiopia to explore the nature of mortality risk, marketing patterns, and herd accumulation dynamics among a poor pastoralist population. What comes through clearly in the data is that marketing plays a very minor role in regulating herd sizes. Rather, calving and mortality are the primary drivers of herd dynamics. Part of the mortality experience is associated with covariate shocks, primarily attributable to low rainfall events, but much is household-specific. An important implication is that although the emphasis in the donor community has been on early warning systems and restocking projects to address covariate shocks, for which there is undeniably a role in the east African ASAL, the prominence of idiosyncratic mortality risk signals an important role also for traditional livestock livestock gifting and loaning practices and other local means by which households can respond to assist each other in time of need.

Perhaps the most alarming find relates to the apparent existence of significant poverty traps, wherein households with roughly fewer than twenty head of cattle face a less than ten percent probability of being able to climb out of their livestock poverty. A herd of that size is generally insufficient to provide a nutritionally adequate supply of calories, protein and micronutrients for a Borana household of seven or so persons. So while the entire system has faced generalized decline of household average herd sizes, the decline in the poorest households' herds is of greatest concern in an environment where nonpastoral options remain extremely limited and, when available, offer extraordinarily low compensation (Little et al.). Pastoral risk remains a serious problem for the most destitute among an extremely poor population.

Figure 1: Mean Household Herd Size

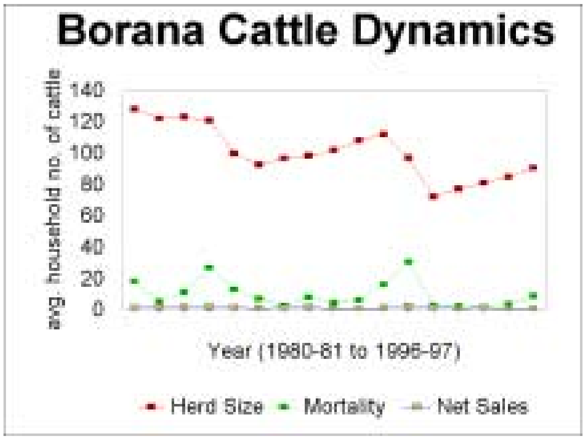

Figure 2. Household herd size cumulative

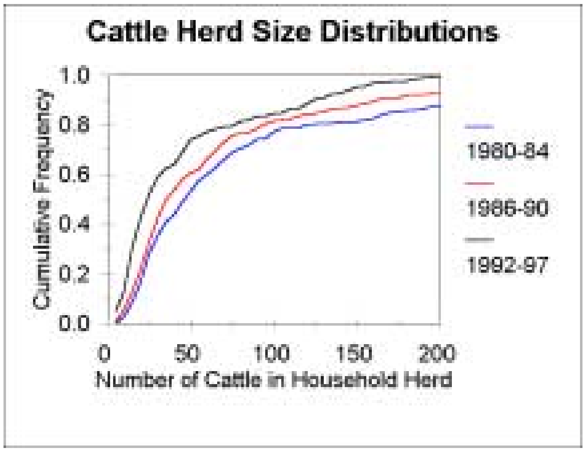

Figure 3: Mean Household Livestock Mortality and Marketing Patterns

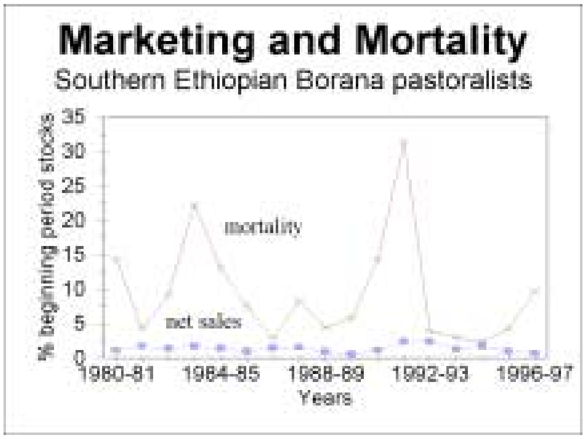

Figure 4. One-year transition scatter plot

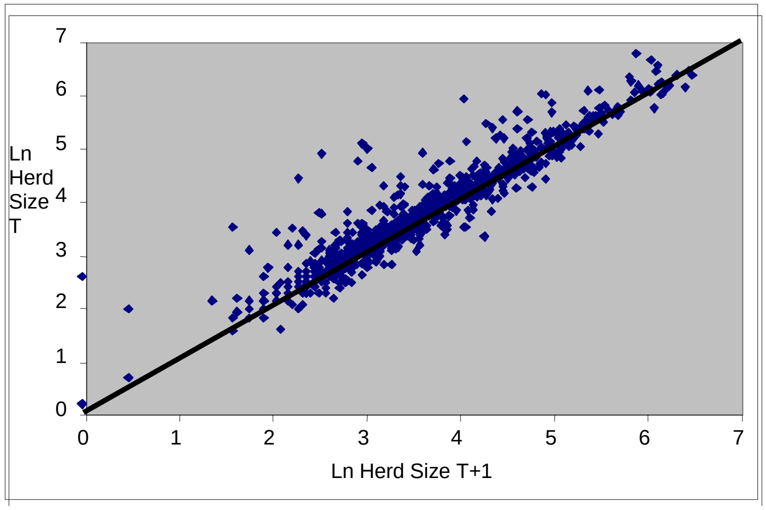

Figure 5. Ten-year transition scatter plot

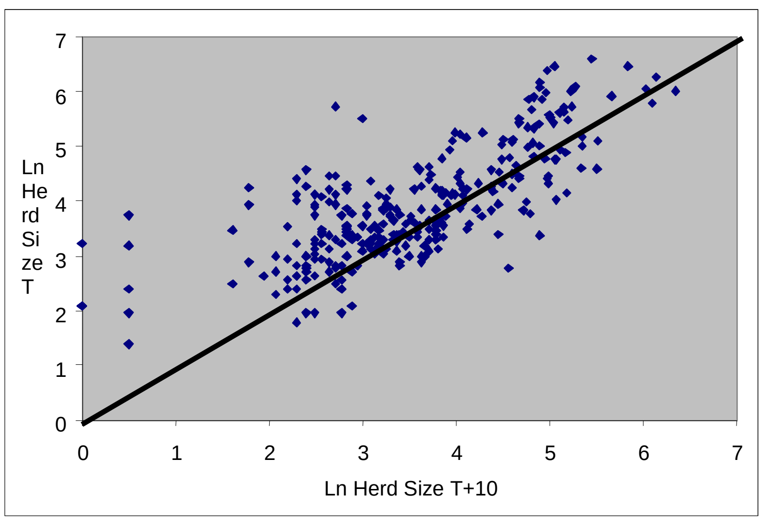

Table 1. Livestock Mortality Model Estimates

Dependent Variable	M_{ijt}		m_{ijt}	
Model #	(1)	(2)	(1')	(2')
Intercept	-28.53789386	-11.51764146	-0.18025938	0.124281553
	7.014285187	9.154755561	0.069296099	0.091447838
Mjt	0.224163686			
	0.076673354			
mjt			0.517813972	
			0.071751736	
High Rainfall		-17.6005931		-0.280378852
		7.125337503		0.070665874
Medium Rainfall		-11.41052357		-0.226744095
		7.282228638		0.071974241
Hjt		-0.073540432		-0.000367707
		0.054900684		0.000547272
Hjt-High Rain		0.04314819		-0.00016098
		0.065779372		0.000658071
Hjt-Med Rain		-0.010938859		-0.000399732
		0.074009011		0.000736579
Hijt	0.524312845	0.531162281	0.002615711	0.002660912
	0.047707946	0.049064298	0.000468038	0.000493327
Hijt^2	-7.71758E-05	-8.30049E-05	-2.95597E-06	-2.99399E-06
	7.41301E-05	7.56949E-05	7.29717E-07	7.62894E-07
Hijt-High Rain	-0.17879603	-0.120620636	-0.000387534	0.000576187
	0.058614084	0.065343181	0.000580607	0.00065921
Hijt-Med Rain	-0.153552744	-0.112742425	-0.000236742	0.000509704
	0.056798226	0.062775873	0.000559752	0.000629098
Hijt^2-High Rain	-0.000419718	-0.000514243	-1.23648E-06	-2.79404E-06
	0.000134202	0.000143089	1.33413E-06	1.45251E-06
Hijt^2-Med Rain	-0.000230885	-0.000298962	-5.71861E-07	-1.76195E-06
	0.00011881	0.000127916	1.17439E-06	1.28732E-06
High Labor	-7.026831929	-8.451843167	-0.068729383	-0.081654651
	5.094760982	5.274322383	0.049869647	0.052755688

Low Labor	-7.244779297	-8.991907873	-0.075294667	-0.108973085
	4.723640022	5.111337921	0.046183984	0.051040133
High Labor-High Rain	2.43294512	4.765045742	-0.019593138	0.011412504
	4.555688594	5.42331672	0.044350887	0.053844656
High Labor-Low Rain	2.491330224	-3.930395602	0.113112563	-0.030882127
	4.79801661	6.002347675	0.046528141	0.059552037
Low Labor-High Rain	-4.075963716	-2.981344561	-0.062814045	-0.041972171
	5.049622217	6.191143157	0.049084226	0.06139265
Low Labor-Low Rain	-3.139449466	-9.896044312	0.045641427	-0.115997315
	5.386459575	6.749677021	0.052483591	0.067162534
Log Likelihood	-2426.291289	-2425.433494	-178.960265	-186.5594545
Proportion Left Censored	0.405	0.405	0.405	0.405
Proportion Right Censored			0.002	0.002

Asymptotic standard errors are reported below the point estimates.

Table 2. Calf Mortality Model Estimates

Dependent variable	CMijt		cmijt	
Model	(1)	(2)	(1')	(2')
Intercept	-11.31139429	-5.417737028	-0.66405357	0.188709304
	3.251153022	4.27876334	0.265609954	0.337322633
CMjt	0.198479188			
	0.114017475			
cmjt			2.859864262	
			0.839716	
High Rainfall		-4.618394431		-0.781359999
		3.446595353		0.26633335
Medium Rainfall		-3.518151107		-0.6267441
		3.497747641		0.269522946
Hjt		-0.016448112		0.000714742
		0.02539259		0.001975805
Hjt-High Rain		-0.000413458		-8.80253E-05
		0.030986116		0.002405009
Hjt-Med Rain		-0.02059145		-0.00269582
		0.034421506		0.002665802
Hijt	0.224001726	0.224133512	0.010546259	0.009448878
	0.021730623	0.0223309	0.001786064	0.001821835
Hijt^2	-0.000131435	-0.000129854	-1.35399E-05	-1.19646E-05
	3.33551E-05	3.40437E-05	2.71369E-06	2.75263E-06
Hijt-High Rain	-0.121821575	-0.102339067	-0.003635881	-0.000771798
	0.027412505	0.030652707	0.002192003	0.002431684
Hijt-Med Rain	-0.05123619	-0.0296193	-0.001202017	0.001848874
	0.025653477	0.028469251	0.002061115	0.002256494
Hijt^2-High Rain	9.68956E-06	-2.21178E-05	1.41467E-06	-3.27348E-06
	6.20607E-05	6.61313E-05	4.93145E-06	5.24944E-06
Hijt^2-Med Rain	-5.56596E-05	-9.25559E-05	-4.84801E-07	-5.31817E-06
	5.31055E-05	5.73062E-05	4.24038E-06	4.5325E-06
High Labor	-1.707280672	-2.441302415	-0.20328673	-0.26633312
	2.339638818	2.417085735	0.186359485	0.19251175
Low Labor	-4.496725639	-5.752234932	-0.452918081	-0.625578408

	2.200122149	2.380492527	0.174112299	0.189727212
High Labor-High Rain	0.671784951	0.802423176	-0.174439101	-0.158827636
	2.184471282	2.623436885	0.169985133	0.202134351
High Labor-Low Rain	1.491012272	-1.048117366	0.304292617	-0.21196878
	2.237583907	2.823617731	0.175450105	0.222152584
Low Labor-High Rain	-0.115016148	-0.579348813	-0.195227323	-0.245551275
	2.385163845	2.940013168	0.184096591	0.227024174
Low Labor-Low Rain	-0.344844133	-3.604261235	0.164855716	-0.47026233
	2.508899932	3.15427717	0.197559717	0.251082736
Log Likelihood	-1590.503369	-1589.063686	-655.4894129	-650.0777587
Proportion Left Censored	0.552	0.552	0.552	0.552
Proportion Right Censored			0.128	0.128

Asymptotic standard errors are reported below the point estimates.

Table 3. Livestock Marketing Model Estimates

	S	s	P	p	NS	ns
Intercept	1.1351	-0.0121	-10.5401	0.0321	-0.1802	0.0448
	0.2850	*0.6920*	*0.0856*	*0.0521*	*0.8882*	*0.0799*
Mijt	0.0127	2.37E-05	-0.0738	-0.0001	0.0250	0.0002
	0.0427	*0.8959*	*0.0396*	*0.2501*	*0.0019*	*0.3379*
High R	0.3303	0.0332	-6.1085	-0.0128	1.0868	0.0374
	0.6920	*0.1547*	*0.2944*	*0.3139*	*0.2613*	*0.0531*
Low R	0.7661	0.0005	5.4314	0.0466	0.0098	-0.0199
	0.4379	*0.9865*	*0.3624*	*0.0016*	*0.9931*	*0.3794*
Hjt x High R	-0.0131	-0.0002	-0.0396	0.0001	-0.0084	-0.0003
	0.0531	*0.4071*	*0.3094*	*0.6003*	*0.2988*	*0.0451*
Hjt x Med R	0.0012	0.0004	-0.1237	-0.0002	0.0165	0.0001
	0.8854	*0.0640*	*0.0224*	*0.1517*	*0.0847*	*0.4363*
Hjt x Low R	-0.0064	0.0002	-0.0645	-0.0001	-0.0025	-0.0001
	0.3876	*0.3252*	*0.1539*	*0.2421*	*0.7761*	*0.6424*
Hijt x High R	0.0310	-0.0004	0.1112	-4.86E-05	0.0127	-0.0006
	0.0005	*0.0910*	*0.0288*	*0.7440*	*0.2520*	*0.0054*
Hijt x Med R	0.0157	-0.0005	0.1866	0.0002	-0.0268	-0.0007
	0.0723	*0.0307*	*0.0003*	*0.0883*	*0.0125*	*0.0018*
Hijt x Low R	0.0083	-0.0004	0.1122	3.09E-05	-0.0148	-0.0005
	0.2398	*0.0424*	*0.0090*	*0.7909*	*0.0940*	*0.0038*
Hijt^2 x High R	-3.97E-05	7.60E-07	-0.0002	-2.23E-08	-1.77E-05	1.09E-06
	0.0316	*0.1517*	*0.0927*	*0.9435*	*0.4445*	*0.0182*
Hijt^2 x Med R	-9.03E-07	9.78E-07	-0.0003	-5.78E-07	6.08E-05	1.11E-06
	0.9562	*0.0380*	*0.0015*	*0.0459*	*0.0030*	*0.0063*
Hijt^2 x Low R	2.81E-06	5.34E-07	-0.0001	-4.77E-08	1.76E-05	5.90E-07
	0.7780	*0.0630*	*0.0867*	*0.7696*	*0.1634*	*0.0192*
High L	0.0047	-0.0049	1.9998	-0.0035	0.2870	-0.0078
	0.9937	*0.7708*	*0.5924*	*0.7078*	*0.6907*	*0.5889*
Low L	-0.7473	-0.0395	6.2110	0.0016	-0.4436	-0.0180
	0.2890	*0.0513*	*0.1762*	*0.8837*	*0.5931*	*0.2766*
High L x High R	-0.3199	-0.0106	4.9584	0.0074	-1.3744	-0.0122
	0.6403	*0.5848*	*0.2702*	*0.4824*	*0.0883*	*0.4478*
High L x Low R	0.3493	0.0126	-7.1607	-0.0433	1.0168	0.0421
	0.6623	*0.5789*	*0.1262*	*0.0004*	*0.2783*	*0.0247*
Low L x High R	0.7809	0.0495	-1.4747	-0.0005	0.7252	0.0282
	0.3510	*0.0376*	*0.7899*	*0.9689*	*0.4535*	*0.1446*
Low L x Low R	0.4865	0.0314	-12.8970	-0.0483	2.2884	0.0477
	0.6092	*0.2487*	*0.0288*	*0.0007*	*0.0389*	*0.0309*
P	0.0967	0.0010				
	0.0032	*0.2718*				
S			0.4217	0.0014		
			0.0657	*0.0639*		
Log Likelihood	-1582.12	385.70	-549.34	899.07		
R-Square					0.1828	0.1730

Table 5. Cattle herd size transition matrices

			Period t+1 Quantile 1	2	3	4	Total
Period t	Quantile	1	0.207	0.029	0.000	0.000	0.236
		2	0.039	0.189	0.035	0.000	0.262
		3	0.007	0.032	0.188	0.026	0.253
		4	0.001	0.006	0.018	0.224	0.249
	Total		0.254	0.256	0.240	0.250	

			Period t+5 1	2	3	4	Total
Period t	Quantile	1	0.138	0.022	0.008	0.000	0.168
		2	0.095	0.128	0.047	0.004	0.274
		3	0.043	0.073	0.124	0.041	0.282
		4	0.004	0.008	0.059	0.205	0.276
	Total		0.280	0.231	0.239	0.250	

			Period t+10 Quantile 1	2	3	4	Total
Period t	Quantile	1	0.143	0.012	0.000	0.000	0.155
		2	0.099	0.111	0.048	0.004	0.262
		3	0.087	0.067	0.115	0.036	0.306
		4	0.020	0.004	0.056	0.198	0.278
	Total		0.349	0.194	0.218	0.238	

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