Livestock Pricing in the Northern Kenyan Rangelands

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May 2001
Revised version prepared for presentation at the annual meetings of the
American Agricultural Economics Association, Chicago, IL, August 5-8,2001

Comments greatly appreciated

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Abstract: This paper uses detailed, transactions-level data and a structural-heteroskedasticity-in-mean model to identify the determinants of livestock producer prices for pastoralists in the drylands of northern Kenya. The empirical results confirm the importance of animal characteristics, periodic events that predictably shift local demand or supply, and especially rainfall on the prices pastoralists receive for animals. Price risk premia are consistently negative in these livestock markets. The imposition of quarantines has a sharp negative effect on expected producer prices in the pastoral areas, revealing a distributionally regressive approach to animal disease control in Kenya.

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Background

The arid and semi-arid lands (ASAL) of northern Kenya are representative of much of the African ASAL, in which many of the continent's poorest subpopulations dwell. Due to infertile soils and low and highly variable rainfall, these lands are ill-suited for intensive crop production, so livestock systems predominate. Human population densities have traditionally been quite low, so extensive pastoralism and transhumance have long characterized ASAL production systems. The various ethnic groups inhabiting the northern Kenyan ASAL depend heavily on livestock for sustenance, through blood, meat, and especially milk. Livestock also serve as a store of wealth, a form of insurance against risk, an important status symbol, a means for securing access to land, and an instrument for establishing social relations, including marriage. The vast majority of ASAL pastoral wealth is in the form of livestock (Little 1992, Coppock 1994, Amanor 1995, Desta 1999, McPeak and Barrett 2001).

Markets have long been a feature of African pastoralist systems, including that of northern Kenya (Kerven 1992). But livestock markets in these areas are widely perceived to suffer significant inefficiencies due to high transactions costs, difficulties in contract enforcement, and limited throughput capacity that leads to inelastic demand and supply, and hence volatile prices (Fafchamps and Gavian 1996, 1997, Bailey et al. 1999). Marketed offtake rates are extraordinary low, for example ranging between only 1.5 and 3.5 percent of beginning period cattle stocks among Boran pastoralists since 1980, with offtake rates less than mortality rates every single year (Desta 1999).[2] Problems of low and variable livestock producer prices rank among the most widespread and serious concerns of pastoralists in the region (Smith et al. 2000, 2001), and likely partially explain pastoralists' low marketed offtake rates. Yet, to the best of our knowledge, Andargachew and Brokken's (1993) study of sheep pricing in highland Ethiopia and Jabbar's (1998) study of small ruminants in southern Nigeria are the only published studies that make use of detailed, transactions-level data to disentangle the effects of various factors on livestock prices in Africa. No one appears to have conducted such analysis yet for large stock nor to have accounted for several of the prospective price determinants we control for in this paper. Our objective in this paper is to advance understanding of the determinants of prices received for various livestock by ASAL pastoralists through econometric exploration of a rich set of transactions-level data from two source markets in northern Kenya and the Nairobi terminal market to which they sell. We pay particular attention to policy-related issues related to institutional and physical infrastructure, security, and animal disease control measures.

The two sites on which we focus, Marsabit and Moyale, are towns in north central Kenya, about 540 and 800 kilometers, respectively, from the capital city and principal market of Nairobi. While they are now each the principal towns of eponymous Districts, during the period of data collection they were the two main towns of one vast Marsabit District, which stretched north from Samburu to the Ethiopian border. The most recent data on poverty in Kenya show that the northern ASAL Districts of Marsabit and Samburu suffer the country's highest poverty rates, 79.7 and 82.3 percent of population, respectively, and that pastoralists comprises a large majority of the poor in both Districts, 75 percent in Marasabit and 63 percent in Samburu (MPND 1998). Both Marsabit and Moyale have regular dyadic markets, in which herders and traders engage in one-on-one bargaining to discover prices and to trade. The marketplaces are basically large fields near town, without supporting institutional or physical infrastructure such as auctions, brokers or stockyards. No paved road exists and banditry and cattle rustling are widespread. A paved highway from Addis Ababa and the Ethiopian highlands terminates at Moyale along the international border. Animal disease outbreaks are common and the Kenyan government, following colonial precedent, uses quarantines regularly to keep diseases from the ASAL from infecting highland dairy herds to the south. Animals mainly flow south from each market toward the terminal market (Dagoretti) in Nairobi.

Data

Staff from the GTZ-Marsabit Development Project (GTZ-MDP) collected detailed data on livestock transactions in Marsabit and Moyale from 1994-1997. The data were collected opportunistically and do not comprise a random sample. Sample sizes therefore vary greatly across markets because of nonconstant enumerator availability. When an enumerator was on site, s/he typically was able to record information on 20-30 livestock transactions per day.[3] Nonrandomness aside, this is one of the richest data sets available on livestock prices in Africa, as most available data series are either period average observations made as part of household surveys or multimarket average time series at district or national level. Transactions level data such as these are scarce anywhere in the developing world. We have almost 24,000 usable observations with complete data across three species (camels, cattle, and goats) in the two markets plus sheep in Marsabit. In addition to recording the negotiated price, GTZ-MDP's enumerators independently examined the animal, recording gender, species, and subjective categorical quality data on the animal's body condition (poor, fair/good, or excellent). The animals were not weighed, so analysis can only be done on a per head basis, not per unit live weight. Buyers were interviewed to determine the means by which the animals were evacuated from market, and the destination and planned use of the animal.

Descriptive statistics are reported in Table 1. A few merit immediate comment. There is a large difference in the average price of camels and cattle sold in the two markets. Cattle sold in Moyale brought 27 percent higher prices than those sold in Marsabit during this period, while the mean camel sales price in Moyale exceeded the mean Marsabit camel price by 71 percent. These differences cannot be explained by transport cost differences, both due to the magnitude of the difference between reasonably proximate towns and, especially, the fact that Moyale is further from the principal terminal market, Nairobi, and so should have a lower, not higher, price in spatial equilibrium were the animals truly identical across markets. Limited available evidence suggests poor spatial integration among these markets, as has been found among other livestock markets in Africa (Fafchamps and Gavian 1996, Barrett et al. 1998, Bailey et al. 1999).

Intermarket mean price differences are instead most likely attributable to differences in the breeds predominating in the two regions, with larger and more productive (in terms of lactation and reproduction) Boran cattle dominant in Moyale and the smaller Rendille/Samburu cattle more common around Marsabit. The Somali camels of the border lands are likewise larger in stature and more productive than their more southern, Gabra cousins (Coppock 1994).[4] These differences are also reflected partly in the characteristics and uses of the animals sold in the two markets. In Marsabit, nearly half the cattle sold are castrates and an overwhelming majority remain locally,[5] with one quarter of animals bought for use for manure or traction – i.e., as inputs to crop production. By contrast, no large ruminants were bought for manure or traction in

Moyale, much smaller shares were castrates, and far more animals were destined for the Nairobi terminal market. Lorry rental for eighteen head of cattle from Moyale to Nairobi in the summer of 1998 cost about KSh40,000, so traders only find it worthwhile to truck relatively more valuable animals (Hussein Mahmoud, personal communication). Consequently, lower quality livestock of all species are more commonly trekked away from Marsabit market, while larger, more productive camels and cattle are almost always trucked away from Moyale.[6] Finally, notice that female animals represent less than one third of sales in each species and market, reflecting pastoralists' preference to sell males when in need of cash. Pastoralists in this region try to retain female animals of breeding and milking age when possible (Coppock 1994, Desta 1999).

We coupled these livestock transactions data with monthly rainfall figures reported from the Marsabit and Moyale meteorological stations, 1991-97 (Figure 1). We computed three and twelve month lagged rainfall volumes[7] to capture short-run and long-run forage and water availability, respectively, the crucial determinants of animal productivity and mortality in this system (Desta 1999). Moyale and Marasabit stations averaged 678 and 623 millimeters per year, 1991-97, respectively. Rainfall is highly variable in this area, as manifest in standard deviations in annual rainfall of 280 and 305 millimeters in Moyale and Marsabit, respectively. We should also note that rainfall at both meteorological stations is perhaps slightly higher than that in the surrounding rangelands, particularly as one moves to the Chalbi desert northwest of Marsabit, where annual average rainfall is less than 200mm (McPeak 1999).

We also gathered data on livestock disease quarantines enforced in the District during the time period studied. Four different quarantines were emplaced for various diseases, including anthrax, rinderpest, and foot and mouth disease (FMD). Some were subjectively assessed by district veterinary officers to have a more serious impact than others (e.g., the FMD quarantine on Moyale from September-December 1996 is believed to have had a greater impact than the anthrax quarantine in the North Horr area of Marsabit District over the same period). We nonetheless treat them uniformly so as not to confuse the introduction of a quarantine with the severity or incidence of particular diseases. Throughout the period, the Kenyan government also enforced a continuous screening requirement for contagious bovine pleuro-pneumonia (CBPP) on all livestock moving from the northern rangelands through the transition town of Isiolo and into the highlands, in order to protect the improved peri-urban dairy herds supplying the country's urban milksheds. So animals being moved south must be held and tested, a process that sometimes took up to three months during the survey period, tying up scarce capital for traders, who generally lack access to more than transactional credit (Little 1992). As a consequence, trader demand for livestock to move to terminal markets is limited by the animal disease control measures in place and there are significant incentives for bribery to circumvent animal health restrictions on movement.

Econometric Methods

We are interested not only in the determinants of expected prices, but also in the factors that explain price risk, as reflected in series conditional variance, and the interactions between the mean and variance of livestock price series, i.e., the price risk premium prevailing in pastoral livestock markets. Toward that end, we employ a structural heteroskedasticity-in-mean (SHM) estimator akin to the generalized autoregressive conditionally heteroskedastic in mean (GARCH-M) estimator commonly used in time series analyses of the relationship between asset pricing and volatility (Engle et al. 1987, Hamilton 1994).

We want to control not only for rainfall, but also for other possible, unobserved sources of seasonality. Livestock pricing surely depends in part on animal health and productivity, perhaps especially for lactating females, both of which depend heavily on seasonal calving, forage availability, migration, and disease dynamics. Moreover, market demand and supply depend in part on pastoralists' seasonal liquidity demands associated with the periodic payment of school fees, seasonal increases in grain prices and pastoralist demand for grains as milk supplies decline, and on seasonality in terminal market demand. As Figure 1 shows, rainfall is bimodally distributed in the region, and the residual seasonality in livestock prices, controlling for rainfall, may likewise be more complex than a simple cyclical pattern over the year. We therefore used a three term sinusoidal function, cos(doy) + sin(doy) + cos(doy)sin(doy), to capture such patterns, where doy≡2ΠDOY, and DOY is the cumulative fraction the year elapsed as of the transaction date (i.e., day of year divided by 365, or by 366 in the case of the 1996 leap year). This is the most parsimonious parametric representation available to capture smooth but potentially multimodal seasonality.

Another prospective complication is that the price data were recorded in nominal terms, and no appropriate deflators are available to control for the effects of generalized inflation. We therefore include a simple linear annual time trend variable to control for first-order inflationary effects. The time trend runs from a value of zero on the first observation date included in the sample (usually in 1994) and increases by the DOY fraction within the year and thus by a full unit every twelve months.

In their study of small ruminant pricing in the Ethiopian highlands and southern Nigeria, respectively, Andargachew and Brokken (1993) and Jabbar (1998) emphasize the importance of religious festivals promoting ritual animal slaughter in stimulating demand and therefore small ruminant prices. So we use a dummy variable to account for the end of *Ramadan*, the Islamic holy month of fasting,[8] since demand gets pushed up by ritual slaughter of sheep by Muslims in the celebration immediately following Ramadan and by regular increased exports from the area by traders who supply small ruminants (goats and sheep) to the Arabian peninsula for ritual slaughter by pilgrims making the *hadj* to Mecca. In addition to the Ramadan dummy, we also include dummy variables for April and December, the customary months for circumcisions and weddings, respectively, in this region,[9] and for the months school fees are paid in northern Kenya (January, May, September). The former two stimulate demand, the latter expands supply.

Finally, we need to take into account characteristics of the animals sold that affect valuation. Andargachew and Brokken (1993) and Jabbar (1998) show that attributes such as condition, breed, age, size, and castration affect the prices livestock fetch at market. While we have no direct observations of animal size, the GTZ-MDP enumerators did record animals that were younger feedstock or in poor physical condition, both characteristics that should imply lower prices, as well as those in excellent condition and males that were castrated, both of which should increase the animal's price.[10] These measures are imperfect, however, so we also expect that we can capture some unobserved lower quality in animals that buyers trek rather than truck from market. Lorries are scarce and expensive to rent in this region. So traders tend only to move higher quality animals by truck. Animals that are trekked incur a greater risk of injury, theft, or disease and tend to loose body mass, further reducing their expected value to the buyer.[11] So knowing that a buyer trekked an animal away from market conveys further implicit information about its expected value to the buyer.

Taking these factors into account, the SHM regression model therefore takes the form

(1) $\ln p_i = \mathbf{X_i'} \quad + \quad h_i + \quad {}_i$

(2) $h_i = \mathbf{Z_i'}$

where the error term, $\sim N(0,h^2)$, is independent across observations, the X vector includes a constant term, the past three and twelve months' local rainfall (in hundreds of millimeters), the unit annual time trend, the sinusoidal seasonality terms, dummy variables for *Ramadan*, circumcisions, weddings and school fees periods, immature feedstock, castrates, poor condition, and excellent condition animals.[12] The base of comparison for the dummy variable coefficients is thus a mature noncastrated male in fair/good condition moved from market by truck without a quarantine in force and outside of the periods of *Ramadan*, circumcisions, weddings or school fees payments. We use the logarithm of the sales price as the dependent variable, so regression coefficients can be interpreted as approximations of the percent price change associated with a unit change in the independent variable. The conditional standard deviation of the natural logarithm of price, h, also enters the conditional mean equation, allowing for the existence of a direct correlation between price levels and variability, i.e., a risk premium expressed in elasticity terms. The conditional standard deviation is in turn regressed on a constant, the unit annual time trend, the sinusoidal seasonality terms, the quarantine dummy variable, and the past three and twelve months' rainfall.[13] Estimating these two equations simultaneously by full information maximum likelihood yields consistent, efficient estimates of the , , and parameters of interest.

Because most of the animals sold for slaughter in the highlands are males, we hypothesized that the effect of quarantine might differ by animal gender. Likewise, because lactation and fertility are important price determinants for female livestock, but less so far males, we expected that the effects of rainfall and seasonality might differ by gender. For these reasons, we began by estimating a model for each market-species pair (e.g., cattle in Marsabit), pooling males and females, then tested for a structural difference in male and female price determinants. In each case, we could reject the null hypothesis that otherwise identical male and female livestock fetch the same price with probability one, so we report below the market-species-gender specific model results (e.g., for female camels in Moyale).

Estimation Results

The SHM estimation results reported in Tables 2-5 demonstrate the intuitive responsiveness of livestock pricing to animal characteristics, climatic variation, and periodic shifts in demand or supply. The expectation that females and castrates earn a premium is clearly born out across all markets and species. The gender differences are apparent in higher estimated intercept terms in the conditional mean equations for females relative to males, while the significantly positive estimates on the castrate dummies in the equations for male animals range from 12 to 26 percent premia over noncastrated males. Animals in excellent condition earn a handsome premium, ranging from 10 percent for ewes in Marsabit to 18 percent for bulls in Marsabit. Conversely, animals in poor condition sell at a steep discount, of as much as 32 percent in the case of cows in Marsabit. There are relatively few immature feedstock in the data set, so most of those coefficient estimates are not statistically significantly different from zero, although all are of the expected, negative sign. The estimated discounts for immatures varies considerably across markets and species, but can be deep due to size differences, up to 29 percent for female camels in

Marsabit. Animals trekked from market suffer sharp discounts, too, although these are noticeably higher for cattle (8-17 percent) than for other species (1-10 percent), reflecting in part the lesser mobility and greater risk of injury and weight loss of the larger stock that makes the costs of trekking cattle relatively greater. As a consequence, animals must really be of lower value not to warrant lorry transport. Collectively, likelihood ratio test statistics in each regression model corroborate that animal characteristics exert considerable influence over the prices pastoralists receive for their animals.

Previous studies have observed that rainfall affects livestock pricing (Kerven 1992, Fafchamps and Gavian 1997) and our results confirm this intuitive finding, at both the three and twelve month horizons. Across all species and markets, we find that mean livestock prices are increasing in the past twelve months' rainfall, while the conditional standard deviation of price is decreasing in rainfall. The effects of the past three months' rainfall are uniformly larger in magnitude in affecting both the mean and variance of price, as reflected by the positive and statistically significant coefficients on the three-month rainfall variable, which captures the effects of recent rainfall events over and above accumulated annual precipitation. Likelihood ratio statistics permit rejection with probability one of the null hypothesis that rainfall has no effect on prices for each of the market-species models presented.

These findings are consistent with findings from elsewhere in the east African ASAL that livestock prices and mortality rates are negatively correlated, implying that prices do not move to stabilize pastoralist incomes in the face of yield shocks, as is the prevailing wisdom with respect to cropping systems (Coppock 1994, Lybbert et al. 2000). In such cases, market price instability compounds rather than ameliorates entitlements losses in the rangelands. So good rainfall years raise and stabilize livestock prices while drought years lead to low and unstable prices, thereby creating disincentives to reducing herds through sales in times of stress. This helps explain the puzzle of low marketed offtake rates that contribute to pronounced livestock cycles in the ASAL (Fafchamps 1998).

Drought has long been viewed as the primary threat to pastoralists, and for good reason. As forage and water availability decline, livestock productivity suffers, risk of mortality increases, conflict over remaining grazing and watering areas intensifies, and grain prices typically rise (Coppock 1994). The short-term results is “stress-sale syndrome’ in which livestock prices drop rapidly as the market is flooded with animals being offloaded to purchase more expensive grain (Kerven 1992). The expected price effects of a hypothetical drought in northern Kenya, characterized by 200 and 300 millimeters less rainfall over three and twelve month horizons, respectively, are shown in Table 6. As one might expect, prices for females respond more vigorously to rainfall than do prices for males in each species and market. This likely reflects the effect of rainfall on forage and water availability, and thus on lactation and calving rates, which are central to the valuation of female livestock. Camel prices are least affected by rainfall, with expected price drops of only 3-12 percent. Sheep face steeper drought-related price drops, ranging from 21 to 34 percent, than either goats or camels. But cattle prices are the ones that suffer most from drought, with cows in Marsabit estimated to lose more than half their value.

Even controlling for rainfall and seasonal ceremonial and liquidity (school fees) effects, residual seasonality remains, as captured by the three sinusoidal terms in the conditional mean and variance equations for each model. These patterns roughly parallel the seasonal rainfall patterns depicted in Figure 1. Prices reach seasonal minima during the November-March dry season for each species, and peak in the April-June period, during and just after the relatively more reliable long rains, when forage and water are most plentiful and pastoralists are most likely to purchase animals to restock after dry season losses.[14] Residual seasonality is most pronounced for female cattle and sheep, which have expected peak-to-trough interseasonal price differentials of more than 60 percent in Marsabit once one accounts for the negative January school fees and positive April ceremonial effects as well. Seasonality is generally sharper in Marsabit than in Moyale and among females, whose lactation and fertility rates depend directly on water and forage available that varies with the seasons. Price seasonality is markedly less for camels, the species physiologically best suited for arid environments with highly variable and seasonal rainfall, and clearly greatest for cattle, the animals most vulnerable to fluctuations in feed and water regime and sheep, since small ruminants are most commonly sold to meet pastoralists' short term cash requirements (Coppock 1994). Price risk also exhibits seasonal patterns, with variability generally moving inversely with expected price levels, i.e., greater volatility when prices are lower and less volatility when prices are higher. Once again cattle price risk clearly exceeds that for camels or goats.

The expected intra-annual price variation in many markets and species appears greater than prevailing interest rates for those with access to interseasonal credit. For animals whose productivity varies relatively little over the course of a year, (e.g., adult bulls or nonlactating camels or goats), there would appear to be significant foregone trading profits, providing indirect evidence of market inefficiency.[15] This apparent intermarket inefficiency seems related to the relatively high per animal costs of intermarket arbitrage (Little 1996, OSSREA 1999), barriers to entry into long haul transport, and poor communications and transport infrastructure that serve to dampen intermarket flows, all factors that engender greater seasonality and volatility in prices in rural source markets such as these (Barrett 1996, 1997). One manifestation of the poor state of spatial market integration is the extraordinarily large and variable Marsabit-Nairobi daily price differentials for male cattle depicted in Figure 2. Since the mean price of cattle in Marsabit during this period was only KSh6683 (Table 1), the implication is that traders in Nairobi commonly receive more than double the price they paid for an animal in Marsabit, but the returns to intermarket livestock trading are extremely volatile. Inefficient spatial arbitrage contributes to the considerable livestock price volatility evident in these northern Kenyan markets and reduces the efficacy of livestock as a form of insurance against yield and grain price shocks.

In addition to periodic seasonal effects, demand for livestock increases at the end of *Ramadan* and during periods of circumcision and wedding ceremonies, generating a predictable positive effect on prices for most gender-species combinations in the two markets. The largest and most often statistically significant effects occur in the case of sheep and goats. And the effects appear somewhat more pronounced in Moyale markets than in Marsabit. The months in which pastoralists must pay school fees for their children exhibit a clear drop in expected price, reflecting a predictable supply increase. This effect is statistically significant only in the case of small stock (goats and sheep) and is larger in Marsabit than Moyale. The spatial difference probably arises because many animals sold in Moyale come from Southern Ethiopia, where there are no school fees (and much lower school attendance rates).

There do not appear to be any clear annual trends in either the mean or variance of these nominal price series, with some positive and some negative and significant coefficient estimates across the series. Given generalized inflation in Kenya, the absence of any significant, consistent upward trend in nominal livestock prices would seem to imply steady deterioration in the real prices pastoralists receive for their animals.

Livestock price risk premia in the market are typically negative, as captured by estimates of the parameter   relating the conditional standard deviation of log prices, h, to the expected log price. This reflects the commonly observed phenomenon that as market prices grow more volatile, those who nonetheless opt to sell their animals at market are somewhat more desperate for cash and so less able or willing to hold out for a good price from traders. This price risk premium magnifies the effects of rainfall and quarantine on expected prices since rainfall has a consistently negative and statistically significant effect on the conditional variance of livestock prices while quarantine has a consistently positive and significant effect. We now turn to a more focused investigation of the effect quarantines have on livestock pricing in northern Kenya and, indirectly, on the distributional implications of this method of animal disease control.

The Effect of Quarantines

The Kenyan government, following colonial precedent, uses animal disease quarantines to protect the herds of the highland regions around Nairobi and the country's other major cities from diseases found in the ASAL regions, especially those of northern Kenya. But quarantines are also explicitly barriers to trade and ranchers interested in reducing competition from pastoralist suppliers sometimes promote quarantines for this fundamentally protectionist reason (Kerven 1992, Little 1992). Because quarantines impede commerce, they reduce demand and thus the prices fetched for livestock from the net exporting regions of northern Kenya. By reducing the number of livestock market participants, quarantines may also make remaining market demand

and supply more price inelastic, thereby fuelling price variability.

These expectations are confirmed in the estimation results. Animal disease quarantines result in substantial estimated revenue losses for herders, with the greatest effects, a drop of 23.7 percent, felt by cattle in Marsabit market (Table 7). Consistent with the conjecture that marketing barriers render demand more inelastic, quarantine's effects on expected prices come mainly through increased price risk, as can be seen by comparing the point estimates associated with the quarantine dummy variable in Tables 2-5 with the estimated net effects reported in Table 7, which accounts for the risk premia effect associated with quarantine's induced effects on price variability. Quarantine's effects are generally greatest on male livestock and on cattle, each of which are more commonly sold for slaughter in terminal markets than are females – commonly retained for milking or breeding – or camels or smaller stock, which are more typically slaughtered locally.

The adverse effects of quarantines on the mean and variance of livestock prices signals a distributionally regressive approach to animal disease control in Kenya at the regional level, whereby the poorest Districts in the country pay a considerable price to protect the herds of the wealthiest, highland Districts. In order to get at the question of the distributional effects of quarantines, we estimated the same SHM model for each gender-species pair in the Nairobi terminal market (results not shown). As reflected in Table 7, quarantine has negligible effects on livestock prices in Nairobi. Quarantine in the northern rangelands has a noticeable effect only on cattle prices and those effects are quite modest, just 15 percent of the corresponding effect in Moyale and 10 percent of that in Marsabit. This suggests that either Nairobi demand is more price elastic than is northern Kenyan livestock supply, that northern Kenyan animals comprise a relatively small share of aggregate Nairobi sales, or both. Plainly, the costs of quarantine in the northern rangelands are borne disproportionately by the region's pastoralists. Since rangelands livestock producers are significantly poorer than highlands beef consumers or ranchers in Kenya, quarantines appear a highly distributionally regressive means of animal disease control. A fruitful extension to the present work would explore alternative means of achieving at least the same level of epidemiological control but with a less regressive distribution of the costs of disease prevention.

Conclusions

This paper demonstrates that the livestock on which Kenya's poorest subpopulations' livelihoods depend exhibit considerable price variability across space, time, and animal characteristics. Prices respond strongly to rainfall, reflecting the direct dependence of livestock health and productivity on climate. Both predictable, regular demand and supply shifts associated with ceremonial events and periodic demand for cash to pay children's school fees and demand shocks due to quarantines likewise move price distributions significantly. Market prices depend as well on the age. gender, and physical condition of the animal sold.

Entitlements failures (Sen 1981) can result from drought, from policy-related shocks such as the imposition of quarantines, and from weak marketing infrastructure that limits integration with the main terminal market in Nairobi and thereby contributes to striking price volatility. Pastoralists bear the brunt of the price variability caused by these factors yet livestock markets do not appear sufficiently well integrated over space and time to buffer pastoralists against local shocks. Seasonal trough-to-peak appreciation in animal prices well in excess of prevailing nominal interest rates suggests there exist significant barriers to entry into livestock trading that cause foregone profits in the system.

Since herd sizes in the area are regulated largely by mortality (Coppock 1994, Fafchamps 1998, Desta 1999, McPeak 1999, Lybbert et al. 2000, McPeak and Barrett 2001) rather than by marketing decisions, success in reducing the substantial wealth losses associated with livestock mortality depends in part on making market price signals more attractive to pastoralists so that they will be less likely to gamble on livestock survival. The fact that pastoralists persist in this livelihood in the face of staggering market risk provides a clear indication of the meager opportunities they enjoy and their great vulnerability (Little et al. 2001). Research that can enhance our understanding of pastoral livestock markets functioning and thereby improve their performance thus seems central to any serious strategy to relieve acute poverty in the northern Kenyan rangelands.

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Table 1: Descriptive Statistics

	Camels		Cattle		Goats		Sheep
	Marsabit	**Moyale**	**Marsabit**	**Moyale**	**Marsabit**	**Moyale**	**Marsabit**
No. complete observations	523	684	5712	2402	5974	376	8187
Mean price/animal (Ksh)	3969	6803	6683	8496	1090	1094	837
Std. Deviation Price/animal (Ksh)	2571	1841	3828	3132	719	327	637
Castrates as % animals sold	47.0	6.6	47.5	29.6	58.0	7.3	50.8
Females as % animals sold	25.4	28.4	29.7	21.9	32.2	22.3	32.5
Feedstock as % animals sold	9.9	0.0	4.7	0.5	1.0	0.0	1.0
% animals sold sent to Nairobi*	8.2	25.6	25.4	73.9	39.1	20.5	23.5
% animals trekked from market	72.5	3.8	63.6	6.2	60.7	15.4	61.2
% bought for traction/manure	7.9	0.0	25.0	0.0	39.6	0.0	28.7
% bought for resale/slaughter	79.2	99.9	69.5	99.5	49.1	100.0	70.1
% animals sold during quarantine	21.6	28.5	18.8	14.4	21.1	32.4	18.8
% animals in poor condition	8.4	0.0	7.6	0.04	2.3	0.0	7.7
% animals in excellent condition	67.5	100.0	78.0	99.96	86.2	100.0	73.2

* This includes destinations of Isiolo, a major livestock assembly point at the boundary between the northern rangelands and the urban highland markets, and the former Kenya Meat Commission slaughter facility at Athi River, which mainly serves the Mombasa and Nairobi markets.

Table 2 The Determinants of Cattle Producer Prices in Northern Kenya

	Marsabit				Moyale			
	Male		Female		Male		Female	
E(ln Price)								
Constant	8.003‡	(2.355)	8.947‡	(2.013)	9.235‡	(1.754)	9.355‡	(3.765)
Annual trend	-0.014	(0.014)	-0.044*	(0.023)	0.032	(0.028)	-0.002	(0.042)
Cos(DOY)	-0.011‡	(0.002)	0.047	(0.076)	-0.061*	(0.030)	-0.091	(0.102)
Sin(DOY)	-0.032	(0.092)	0.024*	(0.012)	-0.005*	(0.002)	0.013	(0.024)
Cos(DOY)Sin(DOY)	0.063	(0.042)	-0.132	(0.087)	0.046	(0.095)	-0.095*	(0.045)
Ramadan	0.022	(0.012)	0.002	(0.005)	0.023	(0.024)	-0.003	(0.003)
School Fees	-0.072‡	(0.023)	-0.024‡	(0.010)	-0.003*	(0.001)	-0.009	(0.035)
Circumcisions/Weddings	0.122*	(0.061)	0.019	(0.015)	0.041*	(0.021)	0.025*	(0.012)
Feedstock	-0.125*	(0.064)	-0.022*	(0.012)	-0.124‡	(0.045)	-0.092‡	(0.040)
Poor Condition	-0.273‡	(0.092)	-0.374‡	(0.122)				
Excellent Condition	0.195‡	(0.012)	0.158*	(0.070)				
Trek	-0.131‡	(0.023)	-0.063‡	(0.019)	-0.105‡	(0.042)	-0.113*	(0.057)
Quarantine	-0.103‡	(0.045)	-0.074‡	(0.025)	-0.065‡	(0.021)	-0.035*	(0.017)
Castrate	0.135	(0.092)			0.208‡	(0.074)		
12 mo. rain (100 mm)	0.011*	(0.004)	0.052‡	(0.014)	0.037‡	(0.009)	0.039‡	(0.013)
3 mo. rain (100 mm)	0.070‡	(0.002)	0.106‡	(0.041)	0.081*	(0.040)	0.150‡	(0.024)
h≡std dev(ln price)	-0.184‡	(0.053)	-0.145‡	(0.034)	-0.162‡	(0.032)	-0.114‡	(0.025)

Table 2 (continued) The Determinants of Cattle Producer Prices in Northern Kenya

	Marsabit				Moyale			
	Male		Female		Male		Female	
h≡Std Dev(ln Price)								
Constant	7.459	(3.155)	7.124	(2.455)	7.526	(2.375)	7.649	(3.035)
Annual trend	0.013	(0.041)	-0.013	(0.009)	-0.002	(0.002)	-0.001	(0.232)
Cos(DOY)	0.133	(0.092)	0.263	(0.163)	0.131	(0.075)	0.023	(0.032)
Sin(DOY)	0.056	(0.022)	-0.022	(0.021)	-0.024	(0.011)	-0.024	(0.041)
Cos(DOY)Sin(DOY)	0.072	(0.092)	0.112	(0.036)	0.002	(0.052)	0.231	(0.032)
Quarantine	0.724	(0.321)	0.335	(0.129)	0.590	(0.252)	0.343	(0.041)
12 mo. rain (100 mm)	-0.061	(0.008)	-0.225	(0.095)	-0.102	(0.034)	-0.147	(0.032)
3 mo. rain (100 mm)	-0.034	(0.021)	-0.192	(0.072)	-0.031	(0.009)	-0.035	(0.012)
LR test stat: rainfall	45.4‡		73.3‡		22.1‡		53.1‡	
LR test stat: periodic events (Ramadan, school fees, circumcisions/weddings)	32.3‡		17.2‡		9.9*		8.1*	
LR test: animal condition (poor, excellent, feedstock, trek, castrate)	53.3‡		62.1‡		39.1‡		31.9‡	
LR test: residual seasonality (sin, cos, sin cos)	15.3*		13.1*		18.1‡		14.2*	
LR test: quarantine	28.5‡		18.2‡		14.7‡		6.9*	

Standard errors reported in parentheses

‡ (*) Statistically significantly different from zero at the 1% (5%) level

Table 3 The Determinants of Camel Producer Prices in Northern Kenya

	Marsabit				Moyale			
	Male		Female		Male		Female	
E(ln Price)								
Constant	8.012‡	(1.455)	8.124‡	(2.374)	8.824‡	(3.040)	9.012‡	(3.501)
Annual trend	-0.061	(0.120)	-0.098	(0.193)	-0.053	(0.083)	-0.032*	(0.016)
Cos(DOY)	-0.023‡	(0.007)	-0.023	(0.018)	-0.012	(0.032)	-0.042	(0.135)
Sin(DOY)	0.017	(0.024)	0.009‡	(0.002)	0.011	(0.100)	0.025‡	(0.010)
Cos(DOY)Sin(DOY)	0.024*	(0.010)	0.010	(0.009)	0.009	(0.007)	0.022	(0.017)
Ramadan	-0.012	(0.192)	0.016	(0.011)	0.052‡	(0.023)	0.043	(0.062)
School Fees	-0.023‡	(0.006)	-0.001	(0.006)	0.012	(0.023)	-0.002	(0.006)
Circumcisions/Weddings	0.024	(0.029)	0.001	(0.004)	0.082*	(0.040)	0.024	(0.027)
Feedstock	-0.238‡	(0.109)	-0.124	(0.092)				
Poor Condition	-0.288‡	(0.083)	-0.296*	(0.104)				
Excellent Condition	0.036*	(0.012)	0.130‡	(0.018)				
Trek	-0.054	(0.098)	-0.017	(0.201)	-0.063	(0.066)	-0.012	(0.042)
Quarantine	-0.091‡	(0.036)	-0.063*	(0.032)	-0.061*	(0.030)	-0.035	(0.128)
Castrate	0.091	(0.102)			0.133*	(0.065)		
12 mo. rain (100 mm)	0.007‡	(0.001)	0.013‡	(0.004)	0.007	(0.011)	0.026‡	(0.010)
3 mo. rain (100 mm)	0.004*	(0.002)	0.004‡	(0.001)	0.025*	(0.022)	0.018‡	(0.007)
h≡std dev(ln price)	-0.019‡	(0.005)	0.018	(0.013)	-0.065*	(0.030)	-0.043‡	(0.015)

Table 3 (continued) The Determinants of Camel Producer Prices in Northern Kenya

	Marsabit				Moyale			
	Male		Female		Male		Female	
h≡Std Dev(ln Price)								
Constant	6.846‡	(2.165)	7.124‡	(1.035)	6.937‡	(3.003)	7.103‡	(1.735)
Annual trend	0.010	(0.013)	-0.016	(0.049)	0.007‡	(0.001)	-0.014	(0.192)
Cos(DOY)	0.009	(0.006)	0.058	(0.031)	0.010	(0.102)	0.036	(0.048)
Sin(DOY)	0.045	(0.032)	-0.075‡	(0.029)	0.023	(0.092)	-0.002‡	(0.001)
Cos(DOY)Sin(DOY)	0.103‡	(0.031)	0.023	(0.054)	-0.024	(0.023)	0.013	(0.023)
Quarantine	0.001	(0.008)	-0.015‡	(0.003)	0.019	(0.022)	0.046	(0.053)
12 mo. rain (100 mm)	-0.030‡	(0.012)	-0.009‡	(0.003)	-0.049‡	(0.018)	-0.035‡	(0.010)
3 mo. rain (100 mm)	-0.022‡	(0.009)	-0.008	(0.007)	-0.000	(0.002)	-0.015‡	(0.005)
LR test stat: rainfall	29.8‡		19.3‡		14.5‡		23.4‡	
LR test stat: periodic events (Ramadan, school fees, circumcisions/weddings)	12.3‡		7.2		11.0*		18.2‡	
LR test: animal condition (poor, excellent, feedstock, trek, castrate)	92.1‡		78.3‡		91.2‡		101.2‡	
LR test: residual seasonality (sin, cos, sin cos)	12.3		15.2*		21.1‡		14.7*	
LR test: quarantine	12.5‡		17.2‡		9.9‡		5.4	

Standard errors reported in parentheses

‡ (*) Statistically significantly different from zero at the 1% (5%) level

Table 4 The Determinants of Goat Producer Prices in Northern Kenya

	Marsabit				Moyale			
	Male		Female		Male		Female	
E(ln Price)								
Constant	6.416‡	(3.015)	6.720‡	(1.213)	5.977‡	(2.554)	6.235‡	(3.052)
Annual trend	-0.005‡	(0.001)	-0.001	(0.113)	-0.032‡	(0.008)	-0.001	(0.112)
Cos(DOY)	-0.012*	(0.006)	-0.024	(0.026)	-0.020*	(0.009)	-0.112	(0.621)
Sin(DOY)	0.023	(0.073)	0.058	(0.199)	-0.040	(0.063)	0.010*	(0.004)
Cos(DOY)Sin(DOY)	-0.009	(0.015)	-0.093	(0.080)	0.002*	(0.001)	0.031	(0.082)
Ramadan	0.116‡	(0.027)	0.085	(0.145)				
School Fees	-0.091‡	(0.010)	-0.024*	(0.012)	-0.102‡	(0.004)	-0.001	(0.065)
Circumcisions/Weddings	0.101‡	(0.040)	0.063*	(0.032)	0.182‡	(0.030)	0.012	(0.192)
Feedstock	-0.083*	(0.041)	-0.132‡	(0.027)				
Poor Condition	-0.209‡	(0.098)	-0.196*	(0.094)				
Excellent Condition	0.136	(0.102)	0.082‡	(0.017)				
Trek	-0.098	(0.192)	-0.108*	(0.034)	-0.022*	(0.011)	-0.067*	(0.033)
Quarantine	-0.018‡	(0.007)	-0.019	(0.102)	-0.011*	(0.006)	-0.009*	(0.004)
Castrate	0.104*	(0.051)			0.028	(0.058)		
12 mo. rain (100 mm)	0.037*	(0.016)	0.046‡	(0.009)	0.024	(0.094)	0.043*	(0.021)
3 mo. rain (100 mm)	0.017‡	(0.003)	0.012‡	(0.003)	0.023*	(0.012)	0.010‡	(0.003)
h≡std dev(ln price)	-0.028‡	(0.008)	-0.093‡	(0.014)	-0.031*	(0.015)	-0.086‡	(0.021)

Table 4 (continued) The Determinants of Goat Producer Prices in Northern Kenya

	Marsabit				Moyale			
	Male		Female		Male		Female	
h ≡ Std Dev(ln Price)								
Constant	6.346‡	(1.951)	6.192‡	(2.751)	6.135‡	(2.095)	5.956‡	(1.632)
Annual trend	0.104	(0.101)	0.024*	(0.011)	0.012	(0.024)	0.023*	(0.012)
Cos(DOY)	0.036‡	(0.052)	0.011	(0.062)	0.002	(0.091)	0.080	(0.222)
Sin(DOY)	-0.041	(0.192)	-0.125	(0.231)	-0.008*	(0.003)	-0.044	(0.047)
Cos(DOY)Sin(DOY)	0.047	(0.029)	0.016	(0.063)	0.081	(0.092)	0.034	(0.109)
Quarantine	0.089‡	(0.031)	0.046‡	(0.019)	0.010‡	(0.001)	0.015	(0.045)
12 mo. rain (100 mm)	-0.007‡	(0.001)	-0.036*	(0.016)	-0.025	(0.102)	-0.046*	(0.022)
3 mo. rain (100 mm)	-0.001*	(0.000)	-0.002‡	(0.001)	-0.009‡	(0.002)	-0.013‡	(0.004)
LR test stat: rainfall	72.2‡		85.6‡		23.4*		75.3‡	
LR test stat: periodic events (Ramadan, school fees, circumcisions/weddings)	22.1‡		8.4*		12.4‡		4.7	
LR test: animal condition (poor, excellent, feedstock, trek, castrate)	102.5‡		71.9‡		30.4‡		51.2‡	
LR test: residual seasonality (sin, cos, sin cos)	21.9‡		3.8		13.1*		12.7*	
LR test: quarantine	22.6‡		19.1‡		28.7‡		2.9	

Standard errors reported in parentheses

‡ (*) Statistically significantly different from zero at the 1% (5%) level

Table 5 The Determinants of Sheep Producer Prices in Northern Kenya

	Marsabit			
	Male		Female	
E(ln Price)				
Constant	5.646‡	(0.765)	6.224‡	(2.031)
Annual trend	0.001	(0.413)	-0.001	(0.014)
Cos(DOY)	-0.012	(0.023)	-0.059‡	(0.008)
Sin(DOY)	0.058	(0.082)	0.112*	(0.057)
Cos(DOY)Sin(DOY)	-0.192	(0.110)	-0.224*	(0.062)
Ramadan	0.128	(0.099)	0.091	(0.115)
School Fees	-0.102‡	(0.004)	-0.024*	(0.011)
Circumcisions/Weddings	0.113‡	(0.006)	0.192‡	(0.032)
Feedstock	-0.191‡	(0.071)	-0.215*	(0.105)
Poor Condition	-0.125‡	(0.025)	-0.193	(0.841)
Excellent Condition	0.285‡	(0.059)	0.151‡	(0.042)
Trek	-0.033*	(0.023)	-0.064‡	(0.012)
Quarantine	-0.044‡	(0.045)	-0.014	(0.121)
Castrate	0.082	(0.092)		
12 mo. rain (100 mm)	0.051‡	(0.013)	0.062‡	(0.012)
3 mo. rain (100 mm)	0.024‡	(0.004)	0.059‡	(0.021)
h≡std dev(ln price)	-0.056‡	(0.019)	-0.084‡	(0.012)

Table 5 (continued) The Determinants of Sheep Producer Prices in Northern Kenya

	Marsabit			
	Male		Female	
Constant	5.725‡	(3.155)	6.346‡	(2.455)
Annual trend	0.002	(0.041)	0.021	(0.009)
Cos(DOY)	0.002	(0.092)	0.053	(0.163)
Sin(DOY)	-0.070	(0.022)	-0.132*	(0.021)
Cos(DOY)Sin(DOY)	0.087	(0.092)	0.069	(0.036)
Quarantine	0.273‡	(0.321)	0.160‡	(0.129)
12 mo. rain (100 mm)	-0.029‡	(0.008)	-0.126‡	(0.095)
3 mo. rain (100 mm)	-0.072*	(0.021)	-0.024‡	(0.072)
LR test stat: rainfall	51.2‡		62.1‡	
LR test stat: periodic events (Ramadan, school fees, circumcisions/weddings)	62.3‡		23.4‡	
LR test: animal condition (poor, excellent, feedstock, trek, castrate)	31.8‡		91.5‡	
LR test: residual seasonality (sin, cos, sin cos)	14.8*		27.0‡	
LR test: quarantine	22.3‡		29.5‡	

Standard errors reported in parentheses

‡ (*) Statistically significantly different from zero at the 1% (5%) level

Table 6: Estimated Effects of Drought On Livestock Prices

(hypothetical drop of 200 and 300 millimeters over 3 and 12 months, respectively)

Percent Change		Males	Females
Camels	**Marsabit**	-3.1	-4.6
	Moyale	-8.1	-11.9
Cattle	**Marsabit**	-22.1	-52.3
	Moyale	-33.4	-47.5
Goats	**Marsabit**	-14.6	-17.4
	Moyale	-12.2	-16.3
Sheep	**Marsabit**	-21.3	-34.1

Table 7: Estimated Effects of Quarantine On Livestock Prices

Percent Change		Males	Females
Camels	**Marsabit**	-9.1	-6.4
	Moyale	-6.2	-3.7
	Nairobi	0.2	0.1
Cattle	**Marsabit**	-23.7	-12.2
	Moyale	-16.1	-7.4
	Nairobi	2.4	2.2
Goats	**Marsabit**	-2.1	-2.4
	Moyale	-1.1	-1.0
	Nairobi	0.4	-0.1
Sheep	**Marsabit**	-5.9	-2.7
	Nairobi	0.2	0.1

Figure 1: Northern Kenyan monthly rainfall patterns, 1991-97

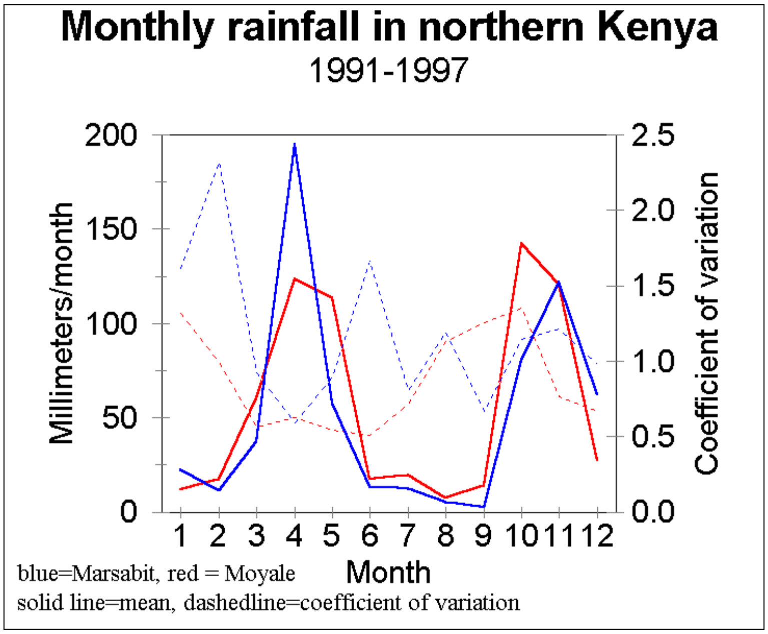
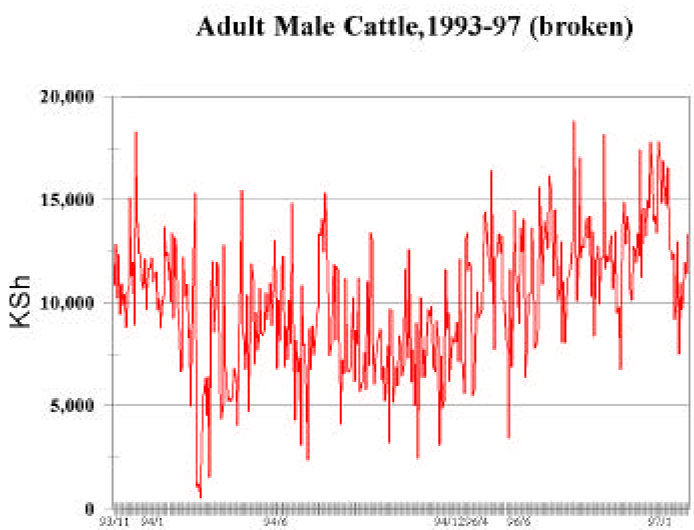


Figure 2: Nairobi-Marsabit Marketing Margins



Source: Barrett et al. (1998)

Notes

[1] This work has benefitted from conversations with Abdillahi Aboud, Christine Cornelius, Solomon Desta, Simeon Ehui, Jibril Hirbo, Vincent Lelei, Winnie Luseno, John McPeak, Kevin Smith, from the comments of seminar participants at the International Livestock Research Institute, and from data assistance by Sheila Nkonge, David Kaplan, and Alison Gilmore. Some of the work was undertaken while visiting the International Livestock Research Institute, whose hospitality is gratefully acknowledged. The data collection was funded by GTZ and the analysis was funded by support to the Global Livestock Collaborative Research Support Program (GL CRSP) from the Office of Agriculture and Food Security, Global Bureau, USAID, under grant number DAN-1328-G-00-0046-00. The views expressed here are those of the authors and do not represent any official agency.

[2] Amanor (1995) and Sieff (1999) report somewhat higher offtake rates in their compilations of published data from other African livestock systems. But all recorded offtake rates in the African ASAL are substantially, often an order of magnitude, lower than equivalent rates from industrialized cattle systems in the high income countries.

[3] Data was also recorded for donkey and poultry transactions, and for sheep in Moyale. But we are unable to use those series due to low numbers of usable observations, often times due to systematically missing information on one or two variables. The analysis is therefore restricted to small (goat and sheep) and large (camel and cattle) ruminants.

[4] Jibril Hirbo (personal communications) adds that because the water around Moyale is relatively salty, camel milk is preferred for tea, the main drink, driving up local demand for female camels.

[5] No doubt some of the animals that buyers declared would remain locally are in fact trekked to the Suguta Marmar market on the Samburu-Laikipia border to the south, where auctions often fetch higher prices for sellers than can be received in Marsabit.

[6] The stark difference in trekking rates could also reflect broader trading patterns. Kenya is a major supplier of manufactured consumer goods (e.g., soap, batteries, plastics) into southern Ethiopia through contraband trade. Trucks transporting such goods from the manufacturing and wholesaling centers in Nairobi, Nanyuki, and other highland urban centers, to Moyale, where contraband is commonly offloaded onto Ethiopian vehicles, commonly backhaul cattle for efficiency's sake. It may be that Marsabit's sparse incoming commercial traffic and the associated dearth of backhaul trucking capacity, partly accounts for the intermarket differentials in rates of animals trekked from market.

[7] We also estimated the models with 6-month lagged rainfall and got qualitatively identical results.

[8] The Islamic calendar varies from the Roman one used for tracking seasonality.

[9] We thank Jibril Hirbo for pointing this out.

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[10] Castrated males gain weight faster and are more docile and thus easier to manage than noncastrated males. Hence the premia typically conferred on castrates.

[11] Weight loss in animals trucked to market is largely excretory and thus is quickly regained once livestock are allowed to eat and drink again (Minish 1979). Trekked animals, by contrast, lose muscle mass that is not regained quickly. So even if animals are of similar quality in the source market, those subsequently trekked will be of lower value in the destination market than those that are trucked.

[12] Animal condition was not clearly recorded in the Moyale data, so we omit the poor and excellent condition dummy variables for series from that market. For a few market-species specific series there were few or no recorded sales of immature feedstock, so that dummy is likewise omitted in those cases. Finally, none of the 376 usable observations on goat sales in Moyale occurred during *Ramadan*, so we omit that dummy variable for that particular model.

[13] An alternative specification of the conditional standard deviation equation including all the dummy variables yielded qualitatively identical results with none of the dummies proving statistically significant.

[14] The residual seasonality found here may also partly reflect the absence of any correction for consumer prices, which typically exhibit seasonality.

[15] The short time series available does not permit direct testing of the efficient markets hypothesis by a method such as that of Garcia et al. (1988).