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Livestock Pricing in the Northern Kenyan Rangelands

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This paper uses detailed, transactions-level data and an innovative, structural-heteroskedasticity-in-mean estimation method 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 that Kenya's approach to animal disease control favours wealthier highlands ranchers and consumers at the expense of poorer drylands herders.

1. 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, while they are well-suited to extensive livestock

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production. Human population densities have traditionally been quite low, so extensive mobile pastoralism and transhumance have long characterised 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 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, and often have entailed elaborate networks of traders and middlemen (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). The literature on east African pastoralists reveals consistently low marketed offtake rates, for example ranging between only 1.5 and 3.5% of beginning period cattle stocks among Boran pastoralists since 1980, with offtake rates less than mortality rates every single year (Desta, 1999) and similar rates of offtake among the Il Chamus and Gabra (Little, 1992; McPeak and Barrett, 2001).[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

[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 industrialised cattle systems in the high income countries. Some of this difference is likely due to higher rates of slaughter for own consumption by herders, but mainly it reflects higher mortality rates.

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 km, 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% of population, respectively, and that pastoralists comprise a large majority of the poor in both districts, 75% in Marasabit and 63% 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. In some cases, brokers (called *dilaal*) are used by both buyers and sellers to find clients and they receive a fixed fee, commonly KSh40 for small ruminants and KSh200 for cattle,[3] for their services equivalent to about 1–2% of the animal's value (Little, 2000; Mahmoud, 2001). The marketplaces are basically large fields near town, without supporting institutional or physical infrastructure such as auctions 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 in Nairobi.

Both Moyale and Marsabit towns represent relatively favourable ecological pockets in an otherwise arid landscape. Rainfed agriculture and mixed agropastoralism are practised in the immediate areas around the towns, but very little cultivation takes place elsewhere and

[3] The exchange rate during this period averaged about KSh70 per US dollar.

mobile pastoralism predominates in those areas. Cattle produce more milk and meat and are therefore more desired in the semi-arid areas, while goats, sheep and camels predominate in the more arid areas ill-suited to cattle. Arid lands predominate in the vicinity of Marsabit, while the semi-arid Boran plateau of southern Ethiopia is the source of many livestock sold in Moyale, so there is some natural inter-market variation in the frequency with which particular species are transacted. Livelihood options outside herding and cultivation are scarce and unremunerative, with a few notable exceptions beyond the reach of poorer pastoralists lacking education and access to significant financial capital (Little *et al*., 2001). Livestock products comprise the bulk of the pastoral diet, except in dry months when considerable amounts of cereals are consumed and herders are compelled to rely on these towns and other settlements in the region. Like many market towns in East Africa, Moyale and Marsabit are multiethnic and strong (even violent) competition between different pastoral groups for grazing and water is common. In the case of Marsabit, some of the different ethnic groups (for example, Boran and Rendille) have their own livestock marketplaces in town to buy and sell their animals, which minimises inter-group interactions and potential confrontations.

The final destination for most of the livestock sold in and exported from Moyale and Marsabit districts is Nairobi, the largest beef market in East Africa. In Nairobi, three important livestock markets account for the bulk of animals sales: Kariobangi (goats and sheep), Njiru (Dandora) (cattle) and Dagoretti (cattle). The largest of the three is Dagoretti, which accounts for sales of about 150,000 cattle per annum (Little, 2000). While the Dagoretti market covers most of southern and western Kenya but includes cattle from northern Kenya and the border areas as well, the Njiru market is almost exclusively for cattle from northern and northeastern Kenya, many of which originate from neighbouring countries (Ethiopia and Somalia). The Njiru market annually accounts for the sale and slaughtering of about 35,000 cattle for the Nairobi market (Little, 2000).

2. Data

Staff from the GTZ–Marsabit Development Project (GTZ–MDP) collected detailed data on livestock transactions in Marsabit and Moyale from 1994 to 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.[4] 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 only.[5] GTZ–MDP's enumerators were trained to observe livestock transactions under negotiation, recording the gender, species and subjective categorical body condition quality (poor, fair/good, or excellent) of the animal over which the bargaining was occurring. If and when a sale was consummated, the enumerator then recorded the final sales price and interviewed the buyer to determine the means by which the animals were to be evacuated from market and the destination and planned use of the animal. The enumerators were well versed in livestock marketing and trained to use quality criteria that were consistent across enumerators, markets and seasons. The animals were not weighed, so analysis can only be done on a per head basis, not per unit live weight.

Descriptive statistics are reported in Table 1. A few merit immediate comment. The different numbers of observations across species and markets reflect the relative frequency with which each type of animal sells in these markets. There is a large difference in the average price of camels and cattle sold in the two markets. Cattle sold in Moyale brought 27% 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%. 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

[4] Data were 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, oftentimes 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.

[5] Sheep are relatively uncommon in the Moyale area and in the surrounding rangelands of southern Ethiopia (Coppock, 1994).

Table 1: *Descriptive Statistics (1 January 1994–30 May 1997)*

	Camels		Cattle		Goats		Sheep
	Marsabit	Moyale	Marsabit	Moyale	Marsabit	Moyale	Marsabit
Number of complete observations	523	684	5,712	2,402	5,974	376	8,187
Mean price/animal (Ksh)	3,969	6,803	6,683	8,496	1,090	1,094	837
Standard deviation price/animal (Ksh)	2,571	1,841	3,828	3,132	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[a]	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

[a]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 serve the Mombasa and Nairobi markets.

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; Teka *et al*., 1999).

Intermarket mean price differences are instead most likely attributable to differences in the nature of the markets and in the breeds predominating in the two regions. Moyale is a major point for loading cattle from either side of the Ethiopia–Kenya border for sale into the Nairobi terminal market. Cattle in the Moyale market are primarily of the larger and more productive (in terms of lactation and reproduction) Boran breed that competes well in the Nairobi market with Maasai cattle coming from Tanzania and Kenya's southern rangelands. Traders based in Moyale, Kenya, often utilise Ethiopia-based middlemen to procure high-quality Boran cattle from Ethiopia, which are then sold and transported to Nairobi (Teka *et al*., 1999). Marsabit's cattle market, by contrast, serves mainly local meat consumers and cultivators who intend to use livestock as draught animals. These are mainly smaller, less productive Rendille and Samburu breed cattle that are hard to sell on the Nairobi market, hence the lower prices and more localised consumption relative to the mainly Boran breed cattle sold out of Moyale (Hussein Mahmoud, personal communication). Marsabit, by contrast, is the primary market for small ruminants (sheep and goats). Indeed, sheep are traded so infrequently in Moyale that we had insufficient observations to analyse (hence the omission from Table 1). Camels in Moyale are largely being sold through Ethiopia or Sudan to export markets on the Arabian peninsula, so these are larger and especially high-quality animals. The camels sold in Marsabit market are routinely younger and smaller, intended mainly for local slaughter and consumption. The Somali camels of the border lands are likewise larger in stature and more productive than their more southern, Gabra cousins, more of which are found in the Marsabit market than in the Moyale market (Coppock 1994).[6]

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, with one-quarter of animals bought for use for manure or traction — i.e., as inputs to crop production.[7] By contrast, no large

[6] Jibril Hirbo (personal communication) 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.

[7] No doubt some of the animals that buyers declared would remain locally were

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. Livestock are more commonly trekked away from Marsabit market, while they are usually trucked away from Moyale.[8] 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, 1991–7 (Figure 1). We computed 3 and 12 month lagged rainfall volumes[9] to capture short- and long-run forage and water availability, respectively — the crucial determinants of animal productivity and mortality in this system (Desta, 1999). Moyale and Marusabit stations averaged 678 and 623 mm per year, respectively, between 1991 and 1997. Rainfall is highly variable in this area, as manifest in standard deviations in annual rainfall of 280 and 305 mm in Moyale and Marsabit, respectively. We should also note that rainfall at both meteorological stations is higher than that in the surrounding rangelands (see earlier discussion), particularly as one moves to the Chalbi desert northwest of Marsabit, where annual average rainfall is less than 200 mm (McPeak, 1999).

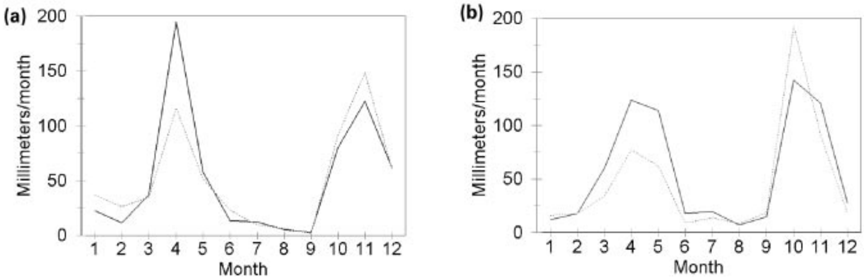
We also gathered data on livestock disease quarantines enforced in the district during the time period studied. Four different quarantines were emplaced for various diseases, including anthrax, rinderpest and

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.

[8] 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. Lorry rental for 18 head of cattle from Moyale to Nairobi in the summer of 1998 cost about KSh40,000 and about KSh30,000 from Marsabit to Nairobi (Hussein Mahmoud, personal communication).

[9] We also estimated the models with 6 month lagged rainfall and obtained qualitatively identical results.

Figure 1: *Monthly rainfall data for Marsabit (a) and Moyale (b) for 1991–7, showing mean (solid line) and standard deviation (dashed line)*



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 to 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 none the less 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 3 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.[10]

3. Econometric Methods

We are interested not only in the determinants of prices, as reflected in

[10] A referee asked about the effect of physical insecurity, manifest commonly in cattle raids on herders or lorries, on price distributions. It would indeed be extremely interesting to see what effect, if any, violence and theft have on prices. Unfortunately, the necessary data on such incidents were not available to us.

the mean conditional on various regressors, 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 introduce and employ a new, structural heteroskedasticity-in-mean (SHM) estimator. This econometric method is a rather straightforward integration of the well-established structural heteroskedasticity model, wherein the conditional variance of the dependent variable is modelled as a function of some subset of the regressors and the generalised 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). Since our data are cross-sectional in nature — they are observations of sales of individual animals at different points in time, not observations of sales of the same animals over time — the GARCH-M approach clearly does not apply directly. We can none the less employ the same principle, simultaneously estimating the mean and standard deviation of the observed transaction price conditional on a set of exogenous regressors, including the estimated conditional standard deviation of price among the regressors in the conditional mean equation. Although to the best of our knowledge this is an entirely original method, it is a rather minor extension to the existing literature on estimation controlling for heteroskedastic errors, so we do not dwell further here on the estimation method.[11]

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

[11] As with a standard GARCH-M model, we first estimate the conditional mean equation by ordinary least squares, then use the standard deviation of the resulting regression residual as the starting value for the intercept term in the conditional standard deviation equation, setting the starting values of the slope coefficients in that equation equal to zero. We then re-estimate the two equations jointly, then subsequently replace the estimated conditional standard deviation regressor in the conditional mean equation with the new estimate from the latest conditional standard deviation equation. This process is repeated following a standard full information maximum likelihood routine until the parameter estimates in both equations satisfy a convergence criterion of 0.0001. The model was coded in GAUSS v. 3.1 and took 2–9 min to converge on a Pentium III processor. Further information is available from the lead author by request.

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 use an innovative, three-term sinusoidal function, $\cos(doy) + \sin(doy) + \cos(doy)\sin(doy)$, to capture such patterns, where $doy \equiv 2\Pi DOY$ and DOY is the cumulative fraction of 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. It is important to note, however, that by controlling for both seasonality and rainfall, the sinusoidal terms capture the central tendency of seasonality patterns based on what one might term predictable climatic variability, while the rainfall variables capture adjustments to those seasonality patterns based on unpredictable intertemporal climatic variability.

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 generalised inflation.[12] 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 12 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. Little (2000) shows the importance of seasonal holidays on market demand in northern Kenya. So we use a dummy variable to account for the end of Ramadan, the Islamic holy

[12] We know from longstanding personal observation that the Nairobi consumer price index (CPI) bears little relation to price movements in Marsabit and Moyale. We prefer the obviously imperfect time trend approach over the potentially more misleading and no more accurate approach of deflating by the wrong price index. Eliminating the time trend and using instead the Nairobi CPI yields no qualitative difference in results.

month of fasting,[13] since demand gets pushed up by ritual slaughter of sheep by Muslims in the celebration immediately following Ramadan. In addition to the Ramadan religious holiday dummy, we also include dummy variables for April and December, the customary months for circumcisions and weddings, respectively, in this region,[14] as well as for the Christian holidays of Easter and Christmas 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 immature feedstock (i.e., younger animals sold for fattening) 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.[15] These measures are imperfect, however, so we also expect that we 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, accounting for as much as much as 70% of market transaction costs (Little, 2000), 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 lose body mass, further reducing their expected value to the buyer.[16] 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

$$\ln p_i = \mathbf{X}_i'\beta + \theta h_i + \varepsilon_i \quad (1)$$

[13] The Islamic calendar varies from the Gregorian calendar used for tracking seasonality.

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

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

[16] 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.

$$h_i = \mathbf{Z}_i'\gamma \tag{2}$$

where the error term, $\varepsilon \sim N(0,h^2)$, is independent across observations, the $\mathbf{X}$ vector includes a constant term, the past 3 and 12 months' local rainfall (in hundreds of millimetres), the unit annual time trend, the sinusoidal seasonality terms, dummy variables for Ramadan, circumcisions, Christian holidays, weddings and school fees periods, immature feedstock, castrates, poor condition, excellent condition animals and quarantine periods, on which a later subsection will focus.[17] 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 religious celebrations, 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 percentage 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. In equation (2), the conditional standard deviation is in turn regressed on the $\mathbf{Z}$ vector comprised of a constant, the unit annual time trend, the sinusoidal seasonality terms, the quarantine dummy variable and the past 3 and 12 months rainfall.[18] Estimating these two equations simultaneously by full information maximum likelihood yields consistent, efficient estimates of the β, θ and γ parameters of interest.

Because most of the animals sold for slaughter in the highlands are males, we hypothesised 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 for 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

[17] 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.

[18] 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.

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 with probability one the null hypothesis that otherwise identical male and female livestock fetch the same price, so we report below the market–species–gender specific model results (e.g., for female camels in Moyale).[19]

4. 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 borne

Table 2: *The Determinants of Cattle Producer Prices in Northern Kenya*

	Marsabit		Moyale	
E(ln price)	Male	Female	Male	Female
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 months rain (100 mm)	0.011** (0.004)	0.052* (0.014)	0.037* (0.009)	0.039* (0.013)
3 months rain (100 mm)	0.070* (0.002)	0.106* (0.041)	0.081** (0.040)	0.150* (0.024)
$h \equiv$ standard deviation (ln price)	–0.184* (0.053)	–0.145* (0.034)	–0.162* (0.032)	–0.114* (0.025)

[19] Estimation of both species and markets together, including interaction effects so as to capture these differences, becomes a bit unwieldy in practice because of the iterative routine needed to achieve convergence. In principle, one could equally estimate the model that way and achieve identical parameter estimates.

Table 2: *Continued*

	Marsabit		Moyale	
	Male	Female	Male	Female
$h \equiv$ standard deviation (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 months rain (100 mm)	–0.061* (0.008)	–0.225* (0.095)	–0.102* (0.034)	–0.147* (0.032)
3 months 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[a]	32.3*	17.2*	9.9**	8.1**
LR test: animal condition[b]	53.3*	62.1*	39.1*	31.9*
LR test: residual seasonality[c]	15.3**	13.1**	18.1*	14.2**
LR test: quarantine	28.5*	18.2*	14.7*	6.9**
Pseudo-R^2	0.348	0.487	0.466	0.563
Number of observations	4,016	1,696	1,876	526

Standard errors reported in parentheses.
*Statistically significantly different from zero at the 1% level; **statistically significantly different from zero at the 5% level.
[a]Ramadan, school fees, circumcisions/weddings.
[b]Poor, excellent, feedstock, trek, castrate.
[c]Sin, cos, sin cos.

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% premia over noncastrated males. Animals in excellent condition earn a handsome premium, ranging from 10% for ewes in Marsabit to 18% for bulls in Marsabit. Conversely, animals in poor condition sell at a steep discount, of as much as 32% 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

Table 3: *The Determinants of Camel Producer Prices in Northern Kenya*

	Marsabit		Moyale	
E(ln price)	Male	Female	Male	Female
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 months rain (100 mm)	0.007* (0.001)	0.013* (0.004)	0.007 (0.011)	0.026* (0.010)
3 months rain (100 mm)	0.004** (0.002)	0.004* (0.001)	0.025** (0.022)	0.018* (0.007)
h ≡ standard deviation (ln price)	–0.019* (0.005)	0.018 (0.013)	–0.065** (0.030)	–0.043* (0.015)
h ≡ standard deviation (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 months rain (100 mm)	–0.030* (0.012)	–0.009* (0.003)	–0.049* (0.018)	–0.035* (0.010)
3 months 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[a]	12.3*	7.2	11.0**	18.2*
LR test: animal condition[b]	92.1*	78.3*	91.2*	101.2*
LR test: residual seasonality[c]	12.3	15.2**	21.1*	14.7**
LR test: quarantine	12.5*	17.2*	9.9*	5.4
Pseudo-R^2	0.543	0.718	0.631	0.709
Number of observations	390	133	490	194

See Table 2 for footnotes.

Table 4: *The Determinants of Goat Producer Prices in Northern Kenya*

	Marsabit		Moyale	
E(ln price)	Male	Female	Male	Female
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 months rain (100 mm)	0.037** (0.016)	0.046* (0.009)	0.024 (0.094)	0.043** (0.021)
3 months rain (100 mm)	0.017* (0.003)	0.012* (0.003)	0.023** (0.012)	0.010* (0.003)
$h \equiv$ standard deviation (ln price)	–0.028* (0.008)	–0.093* (0.014)	–0.031** (0.015)	–0.086* (0.021)
$h \equiv$ standard deviation (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 months rain (100 mm)	–0.007* (0.001)	–0.036** (0.016)	–0.025 (0.102)	–0.046** (0.022)
3 months 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[a]	22.1*	8.4**	12.4*	4.7
LR test: animal condition[b]				
LR test: residual seasonality[c]			21.9*	3.8
LR test: quarantine	22.6*	19.1*	28.7*	2.9
Pseudo-R^2	0.201	0.228	0.397	0.681
Number of observations	4,050	1,924	292	84

See Table 2 for footnotes.

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 months rain (100 mm)	0.051* (0.013)	0.062* (0.012)
3 months rain (100 mm)	0.024* (0.004)	0.059* (0.021)
$h \equiv$ standard deviation (ln price)	–0.056* (0.019)	–0.084* (0.012)
$h \equiv$ standard deviation (ln price)		
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 months rain (100 mm)	–0.029* (0.008)	–0.126* (0.095)
3 months rain (100 mm)	–0.072** (0.021)	–0.024* (0.072)
LR test stat: rainfall	51.2*	62.1*
LR test stat: periodic events[a]	62.3*	23.4*
LR test: animal condition[b]	31.8*	91.5*
LR test: residual seasonality[c]		
LR test: quarantine	22.3*	29.5*
Pseudo-R^2	0.288	0.338
Number of observations	5,526	2,661

See Table 2 for footnotes.

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% for female camels in Marsabit. Animals trekked from market sell at a discounted price too, although these are noticeably higher for cattle (8–17%) than for other species (1–10%), 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. 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 3 and 12 month horizons. Across all species and markets, we find that mean livestock prices are increasing in the past 12 months rainfall, while the conditional standard deviation of price is decreasing in rainfall. The effects of the past 3 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 3 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 stabilise 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. Abundant rainfall raises and stabilises livestock prices, while drought leads to low and unstable prices.

Of course, low and unstable producer prices discourage herders from selling animals in times of stress. Given that restocking through market purchase of fertile heifers is difficult — recall from Table 1 that females (irrespective of fertility) comprise less than one-third of animals in each market — and that herders' future income depends on herd size, managed offtake through sales holds limited appeal in the best of times. Lower and more variable prices only create further disincentives to marketing, thereby helping explain the puzzle of low marketed offtake rates that contribute to pronounced livestock cycles in the ASAL (Little, 1992; Coppock, 1994; Fafchamps, 1998). Rather than selling animals, pastoralists' primary means of coping with low rainfall shocks is to migrate in search of pockets of satisfactory forage and water in an attempt to ride out the climatic shock or, if they lose too many animals to remain mobile, to fall back on pastoral towns and try to survive on free food aid distribution and occasional, low-paying casual labour while maintaining the few livestock they have left (Little *et al*., 2001, McPeak and Barrett, 2001).

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, herders' demand for grains to replace milk in their diet grows and grain prices typically rise (Coppock, 1994). The short-term result is 'stress-sale syndrome' in which livestock prices drop rapidly as the market is flooded with lower-quality animals being offloaded to purchase more expensive grain (Kerven, 1992). Moreover, because animal quality becomes more variable in times of stress, market prices become more volatile. Because cattle have a more pronounced physiological response to changes in rainfall than do goats, sheep or, especially, camels, these effects are greatest among cattle.

Table 6 shows the expected price effects of a hypothetical drought in northern Kenya, characterised by 200 and 300 mm less rainfall over 3 and 12 month horizons, respectively. Drought in this context means cumulative lagged rainfall well below average for that time of year, as we are holding constant (at the sample means) all the regressors other than rainfall. 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%. Sheep face steeper drought-related price drops, ranging from 21 to 34%, 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

Table 6: *Estimated Effects of Drought on Livestock Prices (Hypothetical drop of 200 and 300 mm over 3 and 12 months, respectively)*

		Percentage price 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

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.[20] Residual seasonality is most pronounced for female cattle and sheep, which have expected peak-to-trough interseasonal price differentials of more than 60% 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

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

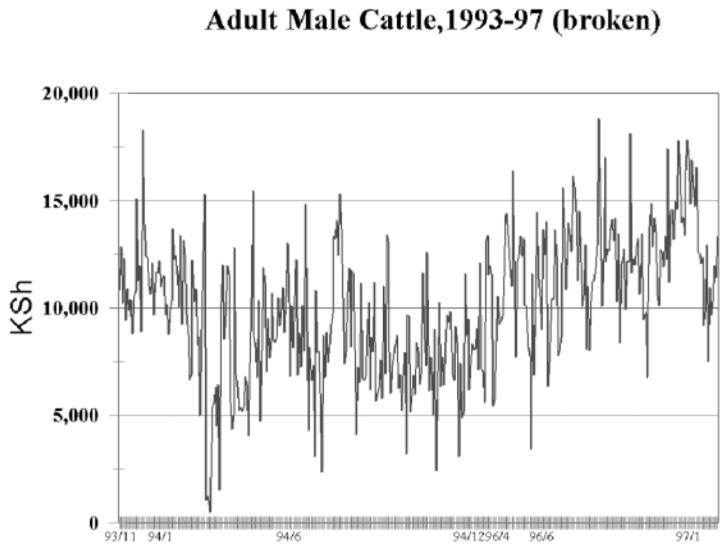
price levels, i.e., greater volatility when prices are lower and less volatility when prices are higher. Once again, cattle price risk clearly exceeds that for camels or goats.

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 non-lactating camels or goats), there would appear to be significant foregone trading profits, providing indirect evidence of market inefficiency.[21] This apparent intermarket inefficiency seems related to the relatively high per-animal costs of intermarket arbitrage (Teka *et al*., 1999; Little, 2000), 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 and high and unstable transport costs — the latter can vary as much as 60% within a few months (Mahmoud, 2001) — contribute 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 during Muslim and Christian holidays 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. 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.

[21] 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).

Figure 2: *Nairobi–Marsabit Marketing Margins (source: Barrett* et al.*, 1998)*



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 generalised 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. This is consistent with what one hears routinely from traders and herders alike in the region and is likely due in large measure to declining real per-capita incomes in urban Kenya over most of the sample period and increasing overvaluation of the Kenyan shilling, leading to reduced domestic and foreign demand for Kenyan meat.

Livestock price risk premia in the market are typically negative, as captured by estimates of the parameter θ 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 none the less opt to sell their animals at market are somewhat more desperate for cash and so are 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.

5. 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 highlands ranchers interested in reducing competition from pastoralist suppliers have sometimes promoted 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%, 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

Table 7: *Estimated Effects of Quarantine On Livestock Prices*

		Percentage price 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

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 that Kenya's approach to animal disease control favours wealthier highlands ranchers and consumers at the expense of poorer drylands herders. The poorer northern districts of Marsabit and Moyale pay a considerable price to protect the herds of the wealthiest, highland districts, such as Laikipia and Nanyuki. 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% of the corresponding effect in Moyale and 10% 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, probably less than 10% (Little, 2000), 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 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.[22]

6. 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. 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

[22] There is much interesting work being done currently — particularly by the African Union/Inter-African Bureau of Animal Resources (AU/IBAR) and the International Livestock Research Institute (ILRI) — on improved preventive and curative animal health care delivery in remote areas of east Africa, utilising paravets, community based animal health care workers, training of private sector vaccine distributors, etc. Since quarantines are routinely circumvented in this region anyway, it is by no means clear that distributionally regressive quarantines are more epidemiologically effective than these other methods of animal disease control. Good comparative cost–benefit analysis of the alternative methods, especially with an eye to the incidence of benefit and cost across the income distribution, remains to be done.

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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