Decomposing Producer Price Risk: An Analysis of Livestock Markets in Northern Kenya

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Abstract: This paper introduces a simple method of price risk decomposition that determines the extent to which producer price risk is attributable to volatile inter-market margins, intra-day variation, intra-week (day of week) variation, or seasonality. We apply the method to livestock markets in northern Kenya, a setting of dramatic price volatility where price stabilization is a live policy issue. Large, variable inter-market basis is the single most important factor in explaining producer price risk in animals typically traded between markets. Local market conditions explain most price risk in other markets, in which traded animals rarely exit the region. Seasonality accounts for relatively little price risk faced by pastoralists in the dry lands of northern Kenya.

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Price volatility concerns producers and governments in a wide range of industries and nations. In settings where producers have little or no access to financial markets through which they can effectively hedge against price risk, governments are often keen to find cost-effective means to reduce producer price volatility. Yet such volatility can arise from any of several sources, so identification of effective intervention strategies depends fundamentally on locating the source(s) of variability in producer prices. This paper introduces a simple method of price risk decomposition that determines the extent to which producer price risk is attributable to volatile inter-market margins, intra-day variation, intra-week (day of week) variation, or seasonality. We apply the method to livestock markets in northern Kenya, a setting of dramatic price volatility where price stabilization is a live policy issue.

Pastoralists residing in the arid and semi-arid lands (ASAL) of northern Kenya are among the poorest subpopulations in sub-Saharan Africa. The region, characterized by poor soils and by low and highly variable rainfall patterns, is ill suited to crop cultivation. Livestock production systems predominate because animals can be moved in response to variable economic, environmental, epidemiological and security conditions. Livestock provide pastoralists not only with meat, milk and blood for sustenance, but also, through livestock sale, with a means for financing basic needs expenditures such as grains, school fees or medical expenses. Livestock prices are therefore a primary determinant of pastoralist wealth and welfare.

Northern Kenyan livestock markets, however, suffer significant inefficiencies due to high transactions costs, difficulties in contract enforcement, physical insecurity, and poor infrastructure. Low and variable producer prices are among the most serious concerns of

pastoralists and likely partially explain the extremely low marketed offtake rates among ASAL pastoralists, which typically languish between 1.5 and 3.5 percent of beginning period cattle stocks and are basically nonresponsive to variation in mortality risk or rangeland carrying capacity (Chabari and Njiru 1991, Bailey et al 1999, Smith et al. 2000, 2001, McPeak and Barrett 2001). Given the difficult and unpredictable environment in which pastoralists pursue their livelihoods, low marketed offtake rates result in considerable loss of wealth through livestock mortality. More frequent and severe climatic shocks in the past two decades have pushed an increasing number of pastoralists deeper into abject poverty, prompting huge flows of international humanitarian aid into the ASAL (McPeak and Barrett 2001).

Many current strategies for reversing this crisis hinge on getting pastoralists to depend *less* on aid and *more* on markets, which in turn depends in part on reducing the extraordinary price volatility that is widely believed to dampen market participation rates. Very few pastoral households enjoy access to formal risk management instruments such as credit, or insurance. Futures markets do not exist. Any near-term dampening of ASAL livestock producer price risk must therefore come through policy or project interventions such as road improvements or the introduction of auctions, local market infrastructure or price broadcasting services. In order to identify suitable interventions, however, one must locate the sources of price risk more precisely.

A Price Risk Decomposition Method

Our method involves a simple decomposition of price risk into four key components: (1) that which is due to prevailing transactional institutions and associated information advantages (intra-day, intra-market variance); (2) that which is due to intra-week variability in market thickness and day-of-the-week effects (inter-day, intra-week, intra-market variance); (3) that

which is due to the costs of spatial arbitrage (intra-week, inter-market variance); and (4) that

which is due to seasonality effects (inter-week, intra-market variance). One can then easily

compute the proportion of total price risk attributable to each of these four components, thereby

locating the source(s) of aggregate price risk. Such information is essential to proper targeting of

any public interventions intended to stabilize producer (or consumer) prices.

   The decomposition method works as follows. Let i index individual transactions, t index

individual days, and w index weeks. Let p be the price in one market (the source market) and p^*

be the price in another market (the destination/terminal market).[1] Then we can decompose the

price for any individual transaction as follows:

$$p_{it} = \left(p_{it} - \overline{p}_t\right) + \left(\overline{p}_t - \overline{p}_w\right) + \left(\overline{p}_w - \overline{p}_w^*\right) + \left(\overline{p}_w^* - \overline{p}^*\right) + \overline{p}^* \tag{1}$$

$$= I_t + M_t + B_t + S_t + \overline{p}^* \tag{2}$$

$I_t \equiv (p_{it} - \overline{p}_t)$ represents the deviation between individual and mean prices in the source market on

a particular day, attributable largely to prevailing transactional institutions and associated

information advantages (e.g., auctions versus bilateral negotiation). $M_t \equiv (\overline{p}_t - \overline{p}_w)$ is the deviation

of the daily mean price from the weekly mean price in the same market, capturing intra-week

variability in market thickness and day-of-week effects. $B_t \equiv (\overline{p}_w - \overline{p}_w^*)$ captures weekly mean

inter-market basis (price differentials between spatially distinct markets), the result of variation

in the costs and performance of inter-market arbitrage. Finally, $S_t \equiv (\overline{p}_w^* - \overline{p}^*)$ is the deviation

between mean terminal market price in the current week and the annual average terminal market

price, $\overline{p}^*$ capturing seasonality effects.

Since $E(I_t) = E(M_t) = E(S_t) = 0$, the unconditional expected value of this relation reflects the conventional spatial market equilibrium relationship, wherein the intermarket price differential is simply the basis:

$$E(p_{it}) = E(B_t) + \bar{p}^*. \tag{3}$$

Of greater interest to us is the source of price risk faced by producers looking to execute a market transaction:

$$V(p_{it}) = V(I_t) + V(M_t) + V(B_t) + V(S_t) + 2[COV(I_t, M_t) + COV(I_t, B_t) + COV(I_t, S_t) +$$

$$COV(B_t, M_t) + COV(S_t, B_t) + COV(M_t, S_t)] \tag{4}$$

This expression leads to an intuitive simplification into four risk sources:

$IR_t \equiv V(I_t) + COV(I_t, M_t) + COV(I_t, B_t) + COV(I_t, S_t)$ is informational/institutional risk

$MR_t \equiv V(M_t) + COV(I_t, M_t) + COV(M_t, B_t) + COV(M_t, S_t)$ is local market risk

$BR_t \equiv V(B_t) + COV(B_t, M_t) + COV(I_t, B_t) + COV(B_t, S_t)$ is basis risk

$SR_t \equiv V(S_t) + COV(S_t, M_t) + COV(S_t, B_t) + COV(I_t, S_t)$ is seasonality risk

One can then substitute these four variables into equation (4) to obtain a straightforward decomposition of price risk:

$$V(P_{it}) = IR_t + MR_t + BR_t + SR_t \tag{5}$$

The proportion of total transactions price risk attributable to each of these four components is then just the individual risk component divided by $V(p_{it})$:

$ir_t \equiv IR_t / V(P_{it})$ (6)

$mr_t \equiv MR_t / V(P_{it})$ (7)

$br_t \equiv BR_t / V(P_{it})$ (8)

$sr_t \equiv SR_t / V(P_{it})$ (9)

By construction, these four unitless risk variables sum to one, offering a simple, intuitive, proportional measure for assessing the source of observed price volatility.

Given other work on livestock markets in Africa (Sandford 1983, Kerven 1992, Fafchamps and Gavian 1997, Bailey et al 1999), we would expect basis risk associated with imperfect spatial arbitrage to emerge as a significant source of price risk. Based on direct observation and pastoralists' own statements (Smith et al. 2000, 2001) we also suspect weak local market institutions account for a nontrivial share of producer price risk in the northern Kenyan ASAL. Because both pastoralists and traders anticipate regular changes in climate and demand due to festivals and holidays, seasonal effects are not expected to be a prominent source of price risk. Ultimately, however, the sources of price risk are an empirical and might well differ across markets.

Data

From January 1996 to December 1997 staff from the GTZ-Marsabit Development Project (GTZ-MDP) collected several thousand observations on livestock transactions in three different markets in Kenya, two source markets in the north, Marsabit and Moyale, and the main terminal market, Dagoretti, in the capital city, Nairobi. Observations from Dagoretti serve as the terminal market prices with respect to both up country markets. During the period of data collection, Marsabit and Moyale were the two main towns of a vast Marsabit District, which stretched north from Samburu to the Ethiopian border, which Moyale town straddles. Both towns hold regular dyadic markets in which herders and traders bargain one-on-one without brokers or other market intermediation. Although livestock trade is the most important economic activity in both Marsabit and Moyale, little investment has been made in marketing facilities. Their

marketplaces are large fields near town, with minimal supporting institutional or physical infrastructure. There are no paved roads in this part of Northern Kenya. Banditry and cattle rustling are widespread and play a critical role in influencing pastoralists' and traders' decisions to participate in markets because animals are commonly trekked to and from remote production areas and markets (Barrett et al. 2001, Chabari and Njiru 1991).

The data were collected opportunistically and therefore do not comprise a random sample. Further, because of nonconstant enumerator availability and the need for sufficient observations within a day and across continuous periods, usable sample sizes vary across markets. In addition to recording the negotiated price, GTZ-MDP's enumerators visually examined each animal and recorded its gender, species and categorical quality data reflecting the animal's body condition (poor, fair, or good). The animals were not weighed, so analysis can only be done on a per head basis, not per kilogram.

Results and Discussion

Results from the price risk decomposition technique applied to these data from Marsabit and Moyale appear in Tables 1 and 2, respectively. Several intuitive findings emerge immediately. First, seasonality accounts for a negligible proportion of producer price risk. Although proposals periodically emerge to reinstate panseasonal pricing that once prevailed under state monopsony and although there is significant predictable seasonal variation in livestock prices due to the region's bimodal rainfall (Barrett et al. 2001), there seems to be little empirical justification to worry about seasonality in price risk. Indeed, because seasonality uniformly covaries negatively with basis, seasonality effects are stabilizing on balance (i.e.,

contribute negatively to producer price risk) in one-third of the gender/species/market-specific series we study.

Size, condition and species are important variables in determining whether animals move only within local markets or instead to terminal markets. Males tend to be of larger size than females of similar condition and are therefore more commonly sold for slaughter in Nairobi, while the latter will tend to be earmarked for local butcheries or for restocking local herds, especially if fertile and in good condition. Indeed, males typically account for three-quarters or more of total market transactions in northern Kenya, while markets in fertile females are very thin (Barrett et al. 2001, McPeak and Barrett 2001). Such patterns prove important to explaining sources of price risk.

Inter-market basis risk (br) proves most influential in those markets in which animals are overwhelmingly destined for slaughter in terminal markets.[2] This describes markets for males of each species in Marsabit, as well as poor condition (generally infertile and nonlactating) cows there (Chabari and Njiru 1991, Barrett et al. 2001). Basis risk is the most important source of producer price risk in almost every such case.

Trade in good condition females of each species is mainly for stock replacement and breeding purposes. As a result, inter-market basis matters relatively little in these markets. Between them, ir and mr consistently account for at least two-thirds of price risk. Female goats in Moyale are a notable exception that proves this rule, because in that area pastoralists raise goats mainly for sale to finance the purchase of cows. When trade is highly localized, price variability emerges naturally from weakness in local markets; the broader economy and volatility in spatial arbitrage have limited impact.

The covariance patterns between I, M, B and S prove interesting as well. As was mentioned already, COV(B,S) < 0 in every case. As terminal market prices reach seasonal highs, inter-market basis falls, likely reflecting heightened competition. This effect is also uniformly the greatest among the six covariances, typically by an order of magnitude. The COV(B,M) term is typically positive and second largest in magnitude. As inter-market basis increases, inter-day differences within the week in source markets tend to rise as well. This likely reflects the adverse effects of higher spatial arbitrage costs on the number of market participants, with transactions prices varying more day-to-day in markets made thinner by high costs of spatial arbitrage. By contrast, I_t is effectively orthogonal to the other three terms. In every case, its covariance with each other risk source accounts for less than one millionth of total producer price variance.

Finally, our results underscore the intuitive importance of controlling for product quality in order to guard against aggregation bias. The final, italicized row in each block of Tables 1 and 2 reports the price risk decomposition results from pooling observations across all body conditions. The apparent share of informational/institutional (intra-day, intra-market) risk consistently increases relative to the condition-specific estimates, often quite considerably so. Since the categorical quality measures available to us surely mask within-category variation and since observed prices are per head, not per kilogram, and there is without question unobserved weight variation, our estimates likely already overstate the importance of informational/institutional risk, further underscoring the relative importance of basis and local market risks in explaining producer price volatility in northern Kenyan livestock markets.

Conclusion

This paper introduces a simple, intuitive method of producer price risk decomposition. Applied to a rich set of transactions-level data from livestock markets in northern Kenya, the statistical results prove quite consistent with qualitative descriptions of the functioning of these markets. Large and variable inter-market basis is the single most important factor in explaining producer price risk in animals typically traded between markets. Local market conditions explain most price risk in other markets, in which traded animals rarely exit the region. Seasonality accounts for relatively little price risk faced by pastoralists in the dry lands of northern Kenya. The practical policy implication of these findings is that high, volatile costs of spatial arbitrage and intertemporally inconsistent competitiveness within and between markets appear the main source of the livestock price volatility that concerns poor pastoralist populations in the northern rangelands. It seems unlikely that one can effectively mitigate the problem of extraordinary livestock producer price risk in northern Kenya without directly improving inter-market arbitrage, whether through efforts to reduce and stabilize transport costs, to improve physical security, or to stimulate new entry into the sub-sector.

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References

Bailey, D. C. B. Barrett, P. D. Little, and F. Chabari. (1999). "Livestock Markets and Risk

Management Among East African Pastoralists: A Review and Research Agenda,"

USAID Global livestock CRSP Pastoral Risk Management Project Technical Report No.

03/99.

Barrett, C. B., F. Chabari, D. Bailey, D. L. Coppock, and P. D. Little. (2001). "Livestock Pricing

in the Northern Kenyan Rangelands," mimeo.

Chabari, F. N., and G. K. Njiru. (1991). "Livestock Marketing, Chapter V," in H. J. Schwartz,

Salim Shaabani and Dierk Walther (eds.) *Range Management Handbook of Kenya,*

Volume II, 1. Marsabit District. Nairobi, Kenya: Ministry of Livestock Development,

Republic of Kenya.

Fafchamps, M. and S. Gavian (1997). "The determinants of livestock prices in Niger," *Journal of*

African Economies 6(2): 255-95.

Kerven, C. (1992). *Customary Commerce: A Historical Reassessment of Pastoral Livestock*

Marketing in Africa. London: Overseas Development Institute.

McPeak, J.G. and C. B. Barrett (2001). "Differential Risk Exposure and Stochastic Poverty

Traps Among East African Pastoralists", *American Journal of Agricultural Economics*,

forthcoming.

Ravallion, M. (1986) "Testing Market Integration," *American Journal of Agricultural Economics*

68 (1):102-109.

Sandford, S. (1983). *Management of Pastoral Development in the Third World*. New York: John

Wiley and Sons.

Smith, K., C. B. Barrett, and P. W. Box. (2000). "Participatory Risk Mapping for Targeting Research and Assistance: An Application Among East African Pastoralists," *World Development*, 28(11): 1945-1959.

Smith, K., C. B. Barrett, and P. W. Box. (2001). "Not Necessarily in the Same Boat: Heterogeneous Risk Assessment Among East African Pastoralists," *Journal of Development Studies*, forthcoming.

Snedecor, G.W. and W. G. Cochran (1989), *Statistical Methods*, eighth edition (Ames, IA: Iowa State University Press).

Table 1: Price Risk Decomposition – Marsabit Data

Species Gender • Condition	ir	mr	br	sr
Cattle Female (Male)				
•Good	0.2724 (0.1279)	0.3721 (0.1944)	0.2365 (0.4640)	0.1189 (0.2136)
•Fair	0.1188 (0.0236)	0.2031 (0.1413)	0.5726 (0.7321)	0.1054 (0.0856)
All	*0.3693 (0.4083)*	*0.3650 (0.2628)*	*0.2099 (0.3414)*	*0.0558 (-0.0125)*
Goats Female (Male)				
•Good	0.3092 (0.1604)	0.4052 (0.2597)	0.2307 (0.5966)	0.0548 (-0.0167)
•Fair	0.3656 (0.6686)	0.3526 (0.1044)	0.3283 (0.1981)	-0.0465 (0.0289)
All	*0.5305 (0.2432)*	*0.2826 (0.2866)*	*0.1733 (0.4801)*	*0.0136 (-0.0099)*
Sheep Female (Male)				
•Good	0.5487 (0.3496)	0.2584 (0.3142)	0.1715 (0.3988)	0.0214 (-0.0627)
•Fair	0.5052 (0.2070)	0.2180 (0.2693)	0.2078 (0.3143)	0.0690 (0.2093)
•Poor	0.1962 (0.0336)	0.3127 (0.4808)	0.3078 (0.4009)	0.1833 (0.0847)
•*All*	*0.6545 (0.6670)*	*0.1822 (0.1725)*	*0.1503 (0.1140)*	*0.0130 (0.0464)*

Female(Male): Cattle[N^{All}=647(681), N^{Good}=355(345), N^{Fair}=109(58)]; Goats[N^{All}=572(198), N^{Good}=394(151), N^{Fair}=163(45)]; Sheep[N^{All}=1281(1010), N^{Good}=644(368), N^{Fair}=447(350), N^{Poor}=234(289)].

Table 2: Price Risk Decomposition – Moyale Data

Species Gender • Condition	ir	mr	br	sr
Cattle Female (Male) •Good *All*	 0.2731 (0.7785) *0.2981 (0.7841)*	 0.4487 (0.1600) *0.4896 (0.1605)*	 0.3500 (0.0779) *0.3291 (0.0689)*	 -0.0718 (-0.0164) *-0.1169 (-0.0136)*
Goats Female (Male) •Good *All*	 0.1203 (0.3557) *0.1519 (0.3511)*	 0.3366 (0.3179) *0.2089 (0.3182)*	 0.6153 (0.2019) *0.6224 (0.2322)*	 -0.0722 (0.1243) *0.0167 (0.0985)*

Moyale Female (Male): Cattle [N^{All}=364 (792), N^{Good}=364 (792)]; Goats [N^{All}=39 (145), N^{Good}=39 (145)]

Notes

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[1] We maintain the radial markets assumption common to the literature on spatial market

integration (Ravallion 1986). This assumption indisputably holds in this empirical application

since there is a regular flow of animals from northern Kenya to the Nairobi terminal market with

no seasonal flow reversal. The only interruptions to the flow occur during periods of quarantine

due to animal health concerns.

[2] We could not identify an appropriate statistical test for make robust inferences from the sample

descriptive statistics br, ir, mr and sr to differences in population among these producer price risk

components. Such tests invariably assume independence, which clearly does not apply in the

present setting. As merely suggestive evidence, the Bartlett and Levene tests of homogeneity of

variance (Snedecor and Cochrane 1989) across B, I, M and S overwhelmingly reject the null

hypothesis that the variances are the same. For each market-species-condition series, the p-value

of the test statistic was less than 0.001.