The Determinants of Livestock Prices in Niger

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Abstract

Not only does livestock makes an important contribution to rural incomes and export earnings in the Sahel, it is also kept as insurance against weather risk. Fluctuations in livestock prices can therefore trigger food entitlement failures. Using monthly price data from Niger, we show that livestock prices respond to droughts and pasture availability. They are also exposed to aggregate shifts in export revenues and meat demand that affect Niger and its southern neighbor, Nigeria. These shifts add an important element of risk to the livelihood of Sahelian farmers and pastoralists. Famine early warning systems should keep an eye not only on weather shocks but also on macroeconomic conditions and other factors affecting the livestock economy.

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The Sahelian climate is marked by highly variable rainfall over time and space. These features make rainfed agriculture highly risky but produce abundant seasonal pasture. Sahelian farmers and pastoralists[1] have long developed production techniques and livestock species that make extensive livestock raising not only feasible but also economically attractive (Sandford (1983)). The traditional importance of livestock as a source of rural incomes and export earnings in the Sahel has been further reinforced by rapid urbanization along the West African coast and by the rising consumption of meat in the region (e.g., Staatz (1979), Shapiro (1979)).

Livestock, however, is more than a productive investment. One of the strategies Sahelian farmers rely on to protect themselves against weather risk in crop production is the accumulation of livestock as a form of precautionary savings (e.g., Binswanger and McIntire (1987), Reardon, Matlon and Delgado (1988), Ellsworth and Shapiro (1989), Czukas, Fafchamps and Udry (1995)).[2] To be effective, this strategy requires livestock prices to be relatively stable. Numerous famines have indeed been traced to entitlement failures that have as proximate cause a collapse in the livestock-grain terms of trade (e.g., Sen (1981), Reardon, Matlon and Delgado (1988), Webb, Braun and Yohannes (1992)).

We show in this paper that livestock prices in Niger, a representative Sahelian country, respond not only to weather shocks but also to shifts in the rural and urban demand for meat in the country and in neighboring Nigeria. The basis for our analysis is price data on 15 animal categories collected monthly in 38 districts of Niger over a period of 21 years. The questionable quality of the data and the high proportion of

[1] Specialized nomadic herders.

[2] See also Rosenzweig and Wolpin (1993) for evidence that Indian farmers rely on the sale and purchase of bullocks to smooth consumption. For a theoretical discussion of the role of precautionary savings as a hedge against risk, see Zeldes (1989), Kimball (1990), and Deaton (1992a, 1992b).

missing observations are compensated by the sheer number of data points: 87,000 in total. We complement this data with monthly rainfall by district and published statistics on mineral exports and cereal production.

Nigerien livestock prices are highly variable. Over the period 1968-1988, the coefficient of variation for deflated monthly prices ranged between .39 and .52 depending on the category of animal. Regressing prices on annual and monthly dummies, rainfall, and demand shifters, we show that aggregate demand factors are, together with weather shocks, important determinants of animal prices. Consecutive years of drought are shown to have a particularly pernicious effect on livestock prices. Urban meat consumption reflects the varying fortunes of the leading sectors of the economy, mineral exports in particular. The regional integration of livestock markets thus renders livestock producers vulnerable to shocks in mineral export revenues, thereby adding an element of risk to their livelihood.

Although our results need to be confirmed by further work, they serve as a warning against too simple a view of Sahelian economies. Weather is probably not the only culprit for entitlement failures and famines. Shocks affecting other segments of the West African economies also play a role through their effect on urban demand for meat, livestock prices, and thus the value of assets that pastoralists and farmers liquidate in hard times. Famine early warning systems should thus keep an eye on not only on weather shocks but also on macroeconomic conditions and other factors affecting the livestock economy.

The Data

The livestock price data used in this paper were collected on a monthly basis by the Nigerien[3] Department of Animal Resources and Hydrology.[4] The data cover 38 districts or *arrondissements* from January 1968 to December 1988. Subsequent to 1988, the Department of Agriculture reclassified animal categories and the price series are no longer comparable. Fifteen categories of animals are distinguished -- camels, horses, chicken, three categories of goats, three of sheep, and six of cattle. Gathered over an extensive range of time and space, the data are limited both in quantity and quality. Across the sample 42% of the data are missing, which still leaves about 87,000 price observations.[5]

The available data are illustrated in Figure 1 for one category of animal, steer, in five contiguous districts. All price series are interrupted by missing observations, usually at different times. The 1975 data seem to have been lost for all five districts, however; 1976 data are also missing in three districts. There are no data on one of the districts, Madarounfa, prior to 1982 and no data on another one, Aguie, until 1977. Prices in some districts are suspiciously constant for long periods of time. In spite of all these shortcomings, a fairly clear pattern emerges from the data: steer prices tended to rise in the mid 1970’s, to remain relatively stable until 1984, to drop dramatically for a couple of years,

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[3] The adjective "Nigerien" is used here to mean "relative to the country of Niger". It is not to be confused with "Nigerian" which means "relative to the country of Nigeria".

[4] The price data were collected by field agents of the Ministère des Ressources Animales et de l’Hydrologie who submitted their monthly reports to the Direction des Etudes et de la Programmation. Data were entered on a computer by Sarah Gavian as part of her work for the Famine Earning Warning System (FEWS), a USAID Development Assistance Project in Niger, from 1987 to 1989.

[5] Missing observations are due to a variety of causes. In some cases, no animal of a particular category was presented for sale during that month. In others, enumerators failed to collect animal prices. Large chunks of data got lost over the years, or were lent out to researchers who did not return the original data sheets to the Ministry. We also cleaned the data for possible outsiders and miscoded entries.

and to recover partially in 1986. The Niamey consumer price index and the price of the main staple food of livestock producers, millet, are displayed on Figure 2. A visual comparison of the two figures indicates that steer prices increased faster than inflation in the 1970's and that the 1984 drop in steer prices was compounded by a sharp increase in millet price. Understanding why the prices of steer and other livestock behaved in this fashion is the main object of this paper.

No reliable data exist on stocks, consumption, exports, quantities transacted, transportation costs, and movements of animals at the district level (SEDES (1987)). Livestock production and marketing in Niger have, however, been described in micro or sectoral studies, e.g., Eddy (1979) and Makinen and Ariza-Nino (1982). These studies have demonstrated the role that weather shocks play in animal production, and the importance of livestock exports to urban centers and coastal countries.

To capture weather shocks, we use rainfall data from meteorological station reports, averaged by district (Service Agro-Météorologique, Ministère des Transports et du Tourisme, République du Niger). Annual rainfall patterns are depicted in Figure 3 for the country as a whole and for selected districts. Periods of below average rainfall in the early 1970's and 1980's culminated in two droughts, one in 1973 and another in 1984. Rains were relatively stable from 1974 to 1980. The best years were 1967, 1978 and 1988. As the figure shows, rainfall is correlated across districts, but not perfectly.[6]

Aggregate shifters of meat demand are constructed on the basis of the following data. Uranium is Niger's main export, and Nigerien agricultural output is dominated by sorghum and millet (SEDES (1987), Jabara (1991)). We take Niger's combined output of

[6] Coefficients of correlation of rainfall across districts turn around 0.75.

sorghum and millet as a measure of rural incomes other than livestock, and the value of uranium production as a determinant of urban incomes that is independent from rural incomes and livestock prices. Annual data on cereal output in volume and uranium revenues in CFA Francs are taken from République du Niger (1991c). Meat consumption in the region is also influenced by Tabaski, a Muslim holiday widely celebrated in the Sahel, during which it is customary to sacrifice a ram. Tabaski dates, which vary from year to year, are taken from the Muslim religious calendar. Nigerien livestock prices are also affected by livestock exports. In the period under consideration, most of Niger's exports of livestock went to Nigeria, whose economy is dominated by oil production (Eddy (1979), SEDES (1987)). We therefore use oil revenue as a broad measure of Nigerian prosperity. The value of Nigerian annual oil production in Nairas is taken from International Monetary Fund (1992).

To control for inflation in Niger, we use the Niamey African Consumer Price Index (CPI) (République du Niger (1991a, 1991b)). This index is preferred over others because it is the most relevant for Nigerien urban consumers of local meat products. It is used to deflate uranium revenues and, in most of the analysis, animal prices as well. The Nigerian GDP deflator (International Monetary Fund, 1992) is used to deflate Nigerian oil revenues. We also control for the possible effect of exchange rate fluctuations on the value of Nigerien livestock exports toward Nigeria. Two exchange rate series are used: the official exchange rate, available on a monthly basis; and the black market exchange rate, for which rough annual averages are reported in SEDES (1987), p.333. Much of the livestock trade between Niger and Nigeria is believed to bypass border trade regulations and to rely on unofficial currency markets (SEDES (1987), Makinen and Ariza-Nino (1982)).

The Stationarity of Livestock Prices

To analyze Nigerien livestock prices, we must first determine whether they are stationary -- i.e., integrated of degree zero. If prices and demand determinants are not stationary, regressing one on the other may lead to spurious results (e.g., Granger and Newbold (1974), Schimmelpfennig and Thirtle (1994), Trotter (1991)). Visual inspection of the data (Figure 1) leads us to suspect that livestock prices are not stationary. To formally test whether livestock prices are integrated of degree zero, we conduct an augmented Dickey-Fuller (ADF) tests (e.g., Granger (1969), Dickey and Fuller (1979)). All prices are deflated by the Niamey African CPI to abstract from domestic inflation. The following regression is estimated separately for each district and of the 15 animal categories:

$$P_{i,t} - P_{i,t-1} = \mu_i + (\rho_i - 1)P_{i,t-1} + \sum_{j=1}^{3} \rho_{i,j}(P_{i,t-j} - P_{i,t-j-1}) + u_{i,t} \qquad (1)$$

where $P_{i,t}$ is the deflated livestock price in district *i*. If prices have a unit root -- i.e. are non-stationary -- then ρ_i is equal to 1 and the coefficient of $P_{i,t-1}$ should not be significantly different from zero. Because the distribution of the *t* statistic is non standard when the series has a unit root, non-standard threshold values must be used to gauge the significance of the test (Dickey and Fuller (1979), Engle and Granger (1987), Engle and Yoo (1987)). Three lagged values of $P_{i,t-j} - P_{i,t-j-1}$ are included to correct for the possibility that shocks to price changes may be correlated over time.[7] Table 1 reports average ADF test results for each of the 15 animal categories using deflated prices in levels (Column 1).[8] Taken individually, most individual price series appear non-stationary: *t*-

[7] Additional lags have low *t* values and virtually no impact on ADF test results. Due to missing observations, adding more lags leads to a rapid drop in degrees of freedom and thus in the precision of the test.

[8] Similar results (not shown) are obtained using prices in logs.

statistics of the coefficient of $P_{i,t-1}$ are in general above the ADF test critical value of -3.43 that corresponds to a 1% confidence level (Dickey and Fuller (1979), Trotter (1991), Fafchamps and Gavian (1996)).

Running ADF tests separately on each district fails to recognize the panel nature of the data, however. Quah (1994), Leven and Lin (1993) and Im, Pesaran and Shin (1996) have proposed various ways of testing for unit roots in panels. Im, Pesaran, and Shin (1996), hereafter IPS, suggest one test that is easy to compute and applicable to heterogeneous panels. Let N be the number of series, T the length of the panel, and t_{iT} the ADF t-test obtained from equation (1) for district i. Denote the average t statistic as $\bar{t}_{NT} = \frac{1}{N}\sum_{i=1}^{N} t_{iT}$. IPS show that, after suitable normalization, the *average* of the ADF test statistic is asymptotically distributed as a standard normal variable, i.e.:

$$\Gamma_{\bar{t}} \equiv \frac{N^{\frac{1}{2}}(\bar{t}_{NT} - E(t_T))}{Var(t_T)^{\frac{1}{2}}} \rightarrow N(0,\ 1)$$

IPS show that $E(t_T)$ and $Var(t_T)$ do not depend on N or nuisance parameters. They do, however, vary with the number of lagged difference terms that appear in Equation (1). Values of $E(t_T)$ and $Var(t_T)$ are tabulated in IPS for various values of T and various lag numbers. Monte Carlo simulations reported by IPS indicate that the above test has reasonable small sample properties.

Standardized t-bar statistics for Nigerien livestock prices are reported in Table 1, column 2. A test value above -1.65 (-2.33) indicates that the null hypothesis of non-stationarity cannot be rejected at the 5% (1%) confidence level. Results suggest that, if considered as a panel, price series for most animal categories, particularly small ruminants, are probably stationary. Our suspicion of non-stationarity is nevertheless confirmed regarding some of the cattle prices. As could be expected, rainfall tests unambiguously stationary.

To eliminate the effect of an unobserved common time-specific component across districts, IPS suggest subtracting cross-section means from the variable under investigation. Results from this procedure are presented in columns 3 and 4 of Table 1. They indicate that, after subtracting the national average price, all livestock prices test stationary. A common time-specific component thus appears to be responsible for the non-stationarity of some livestock price series. Explaining this common component is the emphasis of the remainder of this paper.

The Determinants of Livestock Price Movements

We now examine how livestock prices evolve over time and what factors influence their movements. Prices from the 38 districts are treated as a panel. We begin by regressing deflated livestock prices for each animal category on local rainfall and yearly, monthly, district, and Tabaski dummies:

$$P_{i,t} = \kappa + \sum_{s=0}^{3} \beta_{i,s} R_{i,t-s} + \lambda_i N_{i,t} + \sum_{j \in J_i} \sum_{s=0}^{3} \beta_{j,s} (R_{j,t-s} - R_{i,t-s}) + \sum_{j \in J_i} \lambda_j (N_{j,t} - N_{i,t}) + \\ + \sum_{o=2}^{21} \theta_o Y_{o,t} + \sum_{m=1}^{11} \gamma_m M_{m,t} + \sum_{k=2}^{38} \alpha_k D_k + \sum_{r=0}^{2} \eta_r T_{t+r} + e_{i,t} \qquad (2)$$

Parameters to be estimated are κ, $\beta_{i,t-s}$, λ_i, $\beta_{j,t-s}$, λ_j, θ_o, γ_m, α_k, and η_r. The J_i's are indices of the three districts most closely neighboring i. The variables are:

$P_{i,t}$ price of livestock in district i at month t divided by the Niamey CPI

$R_{i,t-s}$ rainfall that fell in district i over the 6 months including and preceding month $t-s$, deviated from the sample mean

$N_{i,t}$ cumulative deviation of rainfall from its sample mean, truncated above zero, in district i at month t, i.e. $N_{i,t} = Min\ (0\ ,\ \sum_{s=0}^{3} R_{i,t-s})$.

$Y_{o,t}$ dummy variable for year o at t

$M_{m,t}$ dummy variable for month m at t

D_i dummy variable for district i (i.e., fixed effects)

T_{t+r} dummy variable equal to 1 if Tabaski takes place during month $t+r$

The rationale behind equation (2) is as follows. Rainfall is a major determinant of the availability of pasture and watering holes in the Sahel and, consequently, of the profitability of extensive livestock production (Sandford (1983), Makinen and Ariza-Nino (1982)). Rainfall also exerts a predominant influence on crop output and thus on the production of crop residues that are normally fed to livestock. Rational herd management dictates that animals should be sold when pasture and fodder are unavailable and productivity is low (e.g., Sandford (1983), Livingstone (1991), Fafchamps (1993)). Conversely, herders and farmers are expected to react to good rains by reducing offtake and keeping more animals on the range. Livestock are also held as a form of precautionary saving, that is, as insurance against bad weather shocks (e.g., Rosenzweig and Wolpin (1993), Czukas, Fafchamps and Udry (1995)). Poor rains should incite farmers to sell part of their livestock assets to finance grain purchases.

Productivity considerations and precautionary motives thus operate roughly in the same direction: Sahelian livestock producers are expected to liquidate some of their animals when rains are low and to purchase animals -- or sell fewer of them -- when rains are good. The net aggregate supply of animals in each district should therefore increase when rains are bad and decrease when they are good, generating a downward or upward pressure on local prices. Since we expect livestock prices to be affected not by absolute but by relative rainfall, each rainfall observation is deviated from its monthly district-level mean over the period 1966 to 1988. Rainfall variables in equation (2) measure the amount of rain that fell above or below what normally falls in that district during that period of the year.

Rainfall may also affect the net supply of livestock in subsequent periods. Productivity considerations incite herders to keep more animals on the range after good rains make more pasture available. They should also incite them to liquidate these additional animals and their offspring when rainfall returns to normal and pastures go back to their average level. In this case, good rains today should raise livestock prices today but depress them tomorrow (e.g., Jarvis (1974), Rosen (1987), Rosen et al., (1993)). If, in contrast, the dominant motive for selling and buying livestock is precautionary saving and pasture is not a constraint, then one would expect animals to be bought when rains are good and sold when they are bad (e.g., Zeldes (1989)). In a good year, herders would simply hold onto their assets as insurance against a future bad year.[9] To test the presence of a pasture productivity effect, two years of rainfall are used as explanatory variables in equation (2). If lagged rainfall has a significantly negative sign, this can be interpreted as evidence that pasture availability matters.

Delayed effects may also result from the ecology of rangeland. The effect of a temporary rainfall deficit may be symmetrical to what happens after a temporary surplus: reduction in pasture should induce some immediate livestock sales but, once rains return

[9] We thank an anonymous referee for bringing this interesting distinction to our attention.

to normal, producers will try to rebuild their herds. Two or more bad rainy seasons, however, may deplete the stock of grass in a way that makes it difficult for pasture to regenerate itself (e.g., de Leeuw and de Haan (1983), Perrier (1986), Jarvis and Erickson (1986), Jarvis (1993)). Several years of bad rains may thus have a cumulative detrimental effect on the carrying capacity of the range (e.g., Eddy (1979), Sandford (1983)). If so, one would expect prolonged drought to trigger distress sales of animals and lead prices to plummet. Consecutive years of good rains, in contrast, do not have a noticeable cumulative effect on pasture and should not generate price hikes. Taking advantage of this asymmetry, we test the effect of droughts on pasture availability by including in equation (2) a measure of cumulative negative rainfall shocks over a period of two years:[10] $N_{i,t} = Min\ (0\ ,\ \sum_{s=0}^{3} R_{i,t-s})$. If droughts do not matter and the effect of rainfall is symmetrical, then all rainfall effect should be captured by the four $R_{i,t-s}$ variables and the coefficient of $N_{i,t}$ should not be significantly different from zero.

Because herders move their animals across districts in response to differentials in pasture availability, the net supply of animals in a given district -- and thus livestock prices in that district -- are expected to be influenced by rainfall in neighboring districts. To capture this effect, equation (2) includes rainfall variables $R_{i,t}$ not only in district i itself but also in the three closest neighboring districts.[11] To eliminate multicollinearity with rainfall in neighboring districts, we subtract rainfall in district i from that in other districts.[12]

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[10] Two consecutive years of bad rains are indeed what local livestock producers define as a 'drought' (Solod (1990)).

[11] Neighboring districts were identified by visual inspection of the district map.

[12] Rainfall in neighboring districts may still be collinear, however.

While rainfall can be interpreted as affecting principally the net supply of livestock, monthly dummies $M_{m,t}$ and regional dummies D_i capture combinations of demand and supply effects. Livestock prices movements reflect not only seasonal differences in meat consumption but also seasonal availability of pasture, farmers' desire to reallocate labor to their fields during the agricultural season, and seasonal patterns in calving. Monthly dummies should take care of these effects, if present. Districts vary in the number of animals that are offered for sale, the local demand for meat, and the cost of transporting livestock to other districts. Regional dummies D_i control for the resulting differences in price level among regions. Tabaski dummies are included in equation (2) to control for the periodic effect of the Tabaski festival on meat consumption. Because Tabaski occurs at predictable intervals, it should influence prices not only at the time of the celebration itself but also in preceding months. For this reason, two forward looking Tabaski dummies are included in equation (2) as well.

Annual dummies are left to capture any long lasting movements in livestock prices that are not adequately controlled for by the other regressors. Since livestock prices are deflated, they should not be affected by inflation. If supply shifts and seasonal effects are the only determinants of of movements in livestock prices, rainfall variables and seasonal dummies should capture most of the variation in the dependent variable and annual dummies should be unimportant. It is of course conceivable that dynamic supply effects are not adequately captured by lagged rainfall variables and autocorrelation in the residuals. In that case, annual dummies may display a mild, cyclical pattern (e.g., Rosen, Murphy, Sheinkman (1994)). If, on the contrary, rainfall variables are significant and yet annual dummies show large, non-cyclical changes in livestock prices, this can be interpreted as preliminary evidence that large shifts occurred in the demand for livestock products.

Equation (2) is estimated separately for each of the fifteen animal categories, combining price data from all districts, and using prices in levels. Results in logs (not shown here) are similar. For each regression there are between 5,000 and 6,000 non-missing observations. The number of explanatory variables is 92 -- 20 rainfall variables, 20 yearly dummies, 11 monthly dummies, 37 regional dummies, 3 Tabaski dummies, and an intercept.

Because some of the dependent variables may not be stationary, we must first verify that livestock prices and explanatory variables are cointegrated. It is indeed well known that regressing $I(1)$ variables on each other may lead to spurious results (e.g., Hamilton (1994)). Before we can draw any inference from the results, we must therefore check that the residuals from equation (2) are stationary. To do so, the most commonly used approach is to estimate equation (2) and run the following regression on the residuals $\hat{e}_{i,t}$:

$$\Delta\hat{e}_{i,t} = \delta_i \hat{e}_{i,t-1} + \sum_{i=1}^{3} \Delta\hat{e}_{i,t-i} + u_{i,t} \qquad (3)$$

Equation (3) is run separately on the residuals from each district. The resulting *t*-test statistics averaged over all districts are reported in Table 2. These averages all fall above the 5% critical ADF value of -3.37 that would normally be applied to test for cointegration.[13] This approach fails to control for the panel nature of the data, however. As the standardized *t*-bar test suggested by IPS clearly demonstrate, critical values for stationarity in panel data are much lower than that for single time series. Although IPS do not report values for $E(t_T)$ and $Var(t_T)$ that would be applicable to residuals, we speculate that they are probably not very different from those reported for testing the stationarity of the series themselves. We therefore compute standardized *t*-bar test using the values

[13] Only one explanatory variable, yearly dummies, is non-stationary.

reported in IPS. If they are sufficiently lower than the 1% critical value of -2.33, we can safely conclude that residuals are I(0). The results, reported in column (2) of Table 2, are all well below -2.33. ADF tests conducted on the pooled residuals are also reported (column 3); they are all below the 1% critical ADF value. Finally, there is no noticeable difference in results of these tests between the price series that tested $I(1)$ and those that tested $I(0)$. Taken together, these results lead us to accept the stationarity of residuals, and thus the cointegration between livestock prices and the explanatory variables that appear in equation (2).

To avoid spurious regression in the presence of possibly non-stationary dependent variables, we follow the method suggested by Blough (1992) and correct for first-order autocorrelation in the residuals. Unlike Blough (1992), however, the autocorrelation coefficient is estimated using maximum likelihood.[14] This is because maximum likelihood is superior when livestock prices are stationary, as is the case for most animal series. Durbin-Watson tests indicate that additional autocorrelation terms are not required. ML estimates of the autocorrelation coefficient are presented in column (4) of Table 2 (standard-errors in column 5). They are all well below 1, thus providing further evidence that residuals are stationary.[15] To facilitate interpretation, estimated parameters are summarized in a series of Tables and Figures. Detailed results are available on

[14] In estimating the autocorrelation coefficient, SAS corrects for missing observations using a variant of Kalman filtering (see SAS Institute (1990), Brockwell and Davis (1991)). SAS recommends using the maximum likelihood option when the number of missing observations is large. In practice, we did not observe any noticeable difference between maximum likelihood and Yule-Walker estimates. Because all 38 districts are stacked on top of each other, the estimation algorithm mistakenly takes the last residual for district *i* as the *t-1* residual for the first observation of district *i+1*. To minimize the resulting bias in the estimation of autocorrelation, we 'pad' the data by adding 24 fictitious missing observations at the beginning of each district data.

[15] Based on the autocorrelation estimates and standard errors reported in Table 2, a Bayesian approach would conclude that the residuals are stationary (e.g., Sims (1988), Sims and Uhlig (1991)).

request from the authors.

The Effect of Rainfall

We begin by verifying that rainfall matters. First, we test that livestock prices in one district are significantly influenced by rainfall in neighboring districts. We reestimate equation (2) without rainfall in neighboring districts:

$$P_{i,t} = \kappa + \sum_{s=0}^{3} \beta_{i,s} R_{i,t-s} + \lambda_i N_{i,t} + \\ + \sum_{o=2}^{21} \theta_o Y_{o,t} + \sum_{m=1}^{11} \gamma_m M_{m,t} + \sum_{k=2}^{38} \alpha_k D_k + \sum_{r=0}^{2} \eta_r T_{t+r} + e_{i,t} \qquad (2')$$

and conduct a likelihood ratio test. Let $L(2)$ and $L(2')$ be the log-likelihood values obtained from regressing equations (2) and (2'), respectively. Then the likelihood ratio test $-2[L(2')-L(2)]$ is distributed as a χ-square variable with 15 degrees of freedom. Test results are displayed in the first column of Table 3. They show that, except for two animal categories, rainfall in neighboring districts has a jointly significant influence on livestock prices.

We then test whether local rainfall affects prices. We reestimate equation (2') without any rainfall data:

$$P_{i,t} = \kappa + \sum_{o=2}^{21} \theta_o Y_{o,t} + \sum_{m=1}^{11} \gamma_m M_{m,t} + \sum_{k=2}^{38} \alpha_k D_k + \sum_{r=0}^{2} \eta_r T_{t+r} + e_{i,t} \qquad (2'')$$

The likelihood ratio test $-2[L(2'')-L(2')]$ is distributed as a χ-square variable with 5 degrees of freedom. Test results, shown in the second column of Table 3, indicate that rainfall has a strong significant effect on prices for all animal categories.

Next, we turn to individual parameter estimates. Table 4 summarizes the significance of individual coefficients. As is clear from the table, the drought variable $N_{i,t}$ (which is always negative by construction) has a significant effect on prices for all animal categories except horses: consecutive years of bad rains tend to depress prices. This result indicates that rainfall has a non-linear effect on livestock prices, and can be interpreted as evidence of lasting drought effects on pasture and range carrying capacity. Several drought variables are significant for neighboring districts as well: drought in one place appears to affect livestock prices in nearby districts.

The price response to rainfall over time is best seen by computing an ’impulse response’, that is, by simulating the effect of a single shock in rainfall. We consider a shock equivalent to one standard deviation in rainfall and assume that it is shared by all districts. Results (not shown) are are in line with expected productivity effects: good rains raise price in the first year but depress them later; bad rains have the opposite effect. Price reversal seems to occur sooner for small ruminants than for cattle, a possible reflection of the longer gestation lags in cattle than in goats and sheep. These results indicate that pasture matters and that livestock sales and purchases are not affected simply by precautionary savings motives.

Finally we simulate the effect of a drought like the one that took place in 1973. Estimated coefficient predict that a drought of that magnitude would depress the prices of small ruminants by 12.5% on average, and that of cattle by 20.6%. These are large numbers, particularly considering that animal deaths are not included[16] and that millet and sorghum prices may go up at the same time, squeezing terms of trade further against herders (see Figure 2).

[16] Weight loss should, in principle, be captured by market price data.

The Long Run Evolution of Prices

Rainfall shocks may have dramatic effects on livestock sales and purchases, they are not the only force that shapes livestock prices in Niger. Large, non-cyclical shifts appear to be at work as well. Estimated coefficients for annual dummies are reported on Figures 4 for cattle; they are divided by average animal prices to facilitate comparison across livestock categories.[17] Results for other animal categories are very similar. They all show the existence of three clearly distinguishable price regimes: 1968-1975, 1975-1983, and 1983-1988. Livestock prices rose very fast in constant terms from 1968 to 1975, an increase equivalent to 80 percent of the average price. They then remained roughly constant until 1984, at which time they dropped rapidly, only to recover in 1986 and 1987. The similarities across animal categories are particularly remarkable. They indicate that these annual price movements are a robust feature of the data, one that needs to be explained. What could account for the observed evolution?

One may be tempted to attribute the 1984-1985 drop in livestock prices to the 1984 drought (see Figure 3). But equation (2) directly controls for rainfall: if drought is the explanation for the price drop, variable $N_{i,t}$ should have picked it up, not annual dummies. Furthermore, annual dummies fail to display any significant drop in animal value following the 1973 drought and only show a temporary slowing down of an otherwise rapid increase in prices that begun in 1969 and continued until 1975. Price recovery after 1985 does not completely fit weather shocks either. All animal prices rose significantly in 1986, but remained below their 1976-1983 average. The 1987 drop in prices coincided with poor rains (see Figure 3), but it was amplified in the following year even though

[17] Figure 4 uses estimates from regressions in price levels. Virtually identical figures are obtained using the log of price as the dependent variable.

1988 was extremely wet by Sahelian standards. To account for these events, other factors must have been at work, factors that affect not the net *supply* of livestock but the consumption *demand* for livestock products.

Before turning to demand factors, let us first briefly discuss the explanatory power of the other variables that appear in equation (2). Tabaski dummies are significant for small ruminants; they are discussed together with demand variables in the next section. Most regional dummies coefficients are significant; they are examined in a separate paper devoted to spatial market integration (Fafchamps and Gavian (1995)). Monthly dummies are jointly significant. Estimated coefficients for cattle are depicted in Figure 5; similar results were found for other animal categories. Results suggest that animal prices may be as much as 8-10% higher in the dry season than immediately after harvest. Livestock prices tend to rise a little during September, the harvest month -- presumably because farmers save a portion of the revenue from crop sales as livestock. Without data on quantities of livestock held and sold at different times of the year, however, it is difficult to determine precisely what accounts for seasonal movements in prices. In all regressions the estimated autocorrelation coefficients are significantly different from both 0 and 1. They range from .68 to .75 for cattle and from .55 to .60 for small ruminants. These results suggest that livestock prices may be subject to other forces that distill their effect over time, or that variables on the right hand side of equation (2) have an effect on prices over more than one period.

The Role of Demand

In West Africa, eating meat remains a luxury. The aggregate consumption demand for livestock thus depends on consumers' ability to afford meat. To verify whether demand may have been responsible for the long term evolution of livestock prices in Niger, we replace annual dummies by demand shifters in equation (2). The choice of possible shifters is restricted by the limited availability of data. Moreover, demand determinants should be important and yet uninfluenced by livestock prices and as uncorrelated as possible with supply shifters. We identify four potentially important sources of demand variation that satisfy these criteria: Nigerien cereal output A_t; uranium revenues U_t in Niger; oil revenues in Nigeria V_t; and exchange rate distortions X_t between the Nigerian currency, the Naira, and the Nigerien currency, the CFA Franc.

Rural demand varies with agricultural incomes: when harvests are good, rural dwellers are more likely to indulge in meat consumption, and vice versa. Millet and sorghum are the major source of rural income apart from livestock. We therefore expect the last cereal harvest to capture the effect of rural demand for meat and to have a positive effect on livestock prices that is separate from the productivity and precautionary motives discussed above. Since the last cereal harvest is not affected by current livestock prices, we do not have to worry about simultaneity bias. Because rainfall enters as a separate explanatory variable in equation (2), we can safely anticipate that cereal output does not capture weather related supply effects.[18] District level data being unavailable, we rely on national numbers. The evolution of cereal output per head A_t is depicted in Figure 6. The drought years of 1973 and 1984 appear clearly. Bad harvests also occurred in 1975 and 1987. Otherwise, output per head is remarkably constant in the country as a whole.

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[18] As one *Journal* referee pointed out, the cereal output variable also captures the effect of non-weather related income shocks (e.g., locusts) on villagers' precautionary saving behavior and thus on the net supply of livestock from rural areas.

Economic wealth in Western Africa as elsewhere tends to be concentrated in cities. The aggregate demand for meat is thus largely urban (e.g., Eddy (1979), Shapiro (1979)). Urban demand follows the vagaries of the driving sectors of the economy, particularly commodity exports. Uranium revenue is Niger's major export and thus a principal determinant of urban wealth that is uncorrelated with livestock prices. Because the impact of mineral revenues on meat demand presumably takes time to materialize, we rely on annual data, deflated by the Niamey CPI to control for inflation. The evolution of deflated uranium revenues U_t is shown in Figure 6. The value of uranium exports rose very rapidly in the 1970's and culminated in 1979 and 1980. A sharp drop in revenues took place in 1981, after which revenues stabilized at a relatively constant level.

Over the period under consideration (1968-1988) large quantities of livestock were exported from Niger to Nigeria, in part to satisfy the exploding demand for meat that accompanied the oil boom (e.g., SEDES (1987), Makinen and Ariza-Nino (1982)). Oil revenues are therefore chosen to capture a major determinant of Nigerian incomes and demand for meat that is independent from livestock prices. Nominal oil revenues O_t in Nigeria are assumed to shift Nigerian livestock prices P_t^N in an approximatively linear fashion, i.e., $P_t^N = \bar{k} + k_0 O_t$ where k_0 is a constant and $\bar{k}$ is a function of other demand and supply shifters. How much of price movements in Nigeria are reflected in Niger depends on the price transmission mechanism between the two. We want to test whether this transmission mechanism is sensitive to exchange rate movements and whether demand shifts in Nigeria are fully reflected in Niger. To explain how these tests are constructed, we begin by introducing how the oil revenue and the exchange rate disequilibrium variables are constructed, and continue with a discussion of each test.

We utilize three oil revenue variables for the tests. The first one, denoted V_t^d, is constructed simply by deflating Nigerian oil revenues in Nairas by the Nigerian GDP deflator. The second, V_t^o, turns Nigerian oil revenues into CFA Francs using the official exchange rate, and then divides the result by the Niamey CPI. The third, V_t^u does the same, but uses the unofficial exchange rate. An 11 months moving average is used to smooth annual oil revenues into monthly data. The three V_t's are depicted in Figure 7. Using the Nigerian GDP deflator or the unofficial exchange yield roughly the same series. V_t^o displays an artificial peak around 1984, which is due to the overvaluation of the Naira during that period. The Figure shows a rapid increase in the value of Nigerian oil exports culminating with the first oil shock of 1974. Oil revenues fell moderately until 1977, then recovered dramatically during the second oil shock of 1979 and 1980. A collapse of oil revenues followed from 1982 to 1986, followed by short recovery in 1987, and another decline in 1988.

Two measures of exchange rate disequilibrium are also constructed. The first, X_t^o, multiplies the official exchange rate ER_t by the GDP deflator in Nigeria and divide the result by the Niamey CPI. Movements in X_t^o measure differentials of inflation between the two countries that are not fully compensated by exchange rate adjustments. The second measure, X_t^u, is the same except that it uses the unofficial exchange rate. The evolution of both X_t^o and X_t^u is depicted in Figure 8. The figure shows that a large disequilibrium developed in the official exchange rate between 1983 and 1986, a time during which oil revenues were rapidly declining in Nigeria. Using the unofficial exchange rate suggests an opposite movement, with the Naira losing its value relative to the Franc over that same period.

We test whether the price transmission mechanism between Nigeria and Niger is influenced by the exchange rate disequilibrium in the following manner. Suppose that the exchange rate between the Naira and the CFA Franc adjusts instantaneously and perfectly for any inflation differential between the two countries in ways that is not correctly measured by the exchange rate data. In that case, the Nigerien price P_t^n must satisfy:

$$\frac{P_t^n}{P_t^d} = \bar{k} + k_1 \frac{P_t^N}{P_t^D} = \bar{k} + k_2 \frac{O_t}{P_t^D} \tag{4}$$

where k_1 and k_2 are constants and P_t^d and P_t^D are price deflators in Niger and Nigeria, respectively. Regressing livestock prices on $V_t^d \equiv \dfrac{O_t}{P_t^D}$ and either X_t^o or X_t^u should result in a non-significant coefficient for the X_t variable if exchange rate adjustment is indeed instantaneous. If the coefficient of X_t instead turns out to be significantly positive, this can be taken as evidence that exchange rate disequilibrium has an effect on livestock prices: an overvaluation of the Naira relative to the CFA Franc tends to raise livestock prices in Niger.

A test of whether an overvaluation of the Naira is reflected one for one in Nigerien livestock prices is then constructed as follows. Suppose that the transmission of Nigerian inflation through the exchange rate is complete so that $P_t^n = ER_t P_t^N$. In that case, the deflated Nigerien livestock price must satisfy:

$$\frac{P_t^n}{P_t^d} = \frac{P_t^N \, ER_t}{P_t^d} = \frac{k_2 \, O_t \, ER_t}{P_t^d} \tag{5}$$

If we regress livestock prices on X_t^o and $V_t^o \equiv \dfrac{O_t \, ER_t^o}{P_t^d}$, then the coefficient on X_t^o should be 0 if transmission through the official exchange rate is one for one. If we alternatively regress livestock prices on X_t^u and $V_t^u \equiv \dfrac{O_t \, ER_t^u}{P_t^d}$, then X_t^u should not be significant if transmission through the unofficial exchange rate is one for one. If either X_t^o or X_t^u instead turn out to be significantly negative, then this can be interpreted as evidence that the transmission of Nigerian inflation through the exchange rate is less than one for one (more than one for one if the coefficient is positive). Differences between the official and unofficial exchange rate can be interpreted in a similar fashion.

The equation to be estimated is thus:

$$P_{i,t} = \sum_{j \in J_i} \sum_{s=0}^{3} \beta_{j,s} R_{j,t-s} + \lambda N_{i,t} + \sum_{m=1}^{11} \gamma_m M_{m,t} + \sum_{i=2}^{38} \alpha_i D_i + \omega A_t + \chi U_t + \nu V_t + \kappa X_t + \sum_{r=0}^{2} \eta_r T_{t+r} + e_{i,t} \quad (6)$$

The three variables A_t, U_t and V_t capture the effect of agricultural output and mineral exports on the economies of Niger and Nigeria. Their effect on the demand for meat is expected to be positive. Variable X_t captures the effect that differentials of inflation not fully corrected by exchange rate adjustments may have had on livestock prices.

Equation (6) is regressed on the 15 animal categories, for prices in levels and in logs, with four combinations of V_t and X_t variables. As in equation (2), we include Tabaski dummies to capture the effect the festival has on meat consumption. Rainfall variables, monthly dummies and regional dummies are unchanged. All the right-hand side variables that appear in equation (6) were tested for stationarity. We saw in Table 1 that rainfall is stationary. ADF tests with 12 lags indicate that cereal output per head A_t is also stationary (t = -3.934). In contrast, uranium revenues U_t, our three measures of Nigerian oil revenues V_t^d, V_t^o, and V_t^u, and our two measures of exchange rate disequilibrium X_t^o and X_t^u all test non-stationary (t-tests respectively -1.165, -2.234, -2.188, -1.944, -2.530 and -2.090). Each estimated version of equation (6) thus contains three non-stationary explanatory variables.

Since some livestock price series are themselves non-stationary, we must test for cointegration. To do so, we face the same difficulty as for equation (2). To compensate for the absence of a well established method for testing cointegration in panels regressions such as equation (6), we rely on a combination of methods. We begin by running the following regression on the residuals $\hat{e}_{i,t}$ from equation (6):

$$\Delta\hat{e}_{i,t} = \delta_i \hat{e}_{i,t-1} + \sum_{i=1}^{3} \Delta\hat{e}_{i,t-i} + u_{i,t} \tag{7}$$

Average ADF *t*-tests are reported in Table 5, together with IPS standardized *t*-bar tests. As for equation (3), IPS tests are indicative only since we do not have appropriate values of $E(t_T)$ and $Var(t_T)$ for panel cointegration analysis. Residuals from equation (6) with demand shifters appear virtually undistinguishable from those obtained from equation (3) with yearly dummies. ADF *t*-tests conducted on the pooled residuals are identical to those reported for equation (3) (see Table 2). Equation (6) was then reestimated with maximum likelihood correction for first-order autocorrelation in the error term. Estimated values of the autocorrelation coefficient are reported in Table 6. Although slightly higher than for equation (3), they all are well below 1; they are also quite consistent across the four models and across animal categories. Taken together, these results constitute strong evidence that residuals are stationary and that regression (6) does not generate spurious results.

We now turn to parameter estimates. Coefficient estimates for the demand variables in equation (5) are summarized in Table 7.[19] All demand shifters have the anticipated

[19] All the results presented in the remained of this section are from equation (6) with maximum likelihood correction for autocorrelation in the residuals. Given that the dependent and independent variables are cointegrated, this approach is known to yield consistent parameter estimates (e.g., Blough (1992)).

sign and are very significant in virtually all regressions. Individual coefficient values are also remarkably stable across animal categories and models, thereby emphasizing the robustness of the results. Cereal output, Nigerien uranium revenues and Nigerian oil revenues raise the price of all livestock types. Individual *t*-values for uranium and oil are above 10 for virtually all regressions and animal categories. In agreement with expectations, prices of small ruminants anticipate the surge in meat demand that accompanies the celebration of Tabaski. The effect is particularly strong for rams and, to a lesser extent, for castrated rams, the preferred meats for this celebration: the price of rams and castrated rams increases on average by 16-18% and 9%, respectively, in the months or two that precede the celebration. Tabaski demand spills over onto male goats, which serve as ram-substitute for poorer consumers: their price rises by 4-5%. Female goats and sheep increase a bit in price as well -- by 2-5% on average. The effect of Tabaski on large ruminants is generally non-significant, except perhaps for milch cows which seem to be affected negatively.[20]

Columns (1) and (2) under the exchange rate variable summarize test results on whether the transmission of Nigerian demand shifts into Niger is affected by exchange rate disequilibrium.[21] In 60% of the regressions using the unofficial ER_t and several of the regressions using the official ER_t, livestock prices are affected by inflation differentials that are not corrected by exchange rate adjustments. Columns (3) and (4) under the same exchange rate variable summarize test results on whether the transmission of Nigerian inflation to Niger through the exchange rate is one for one. Results

[20] A religious taboo against milking cows around Tabaski may be at work here, although we are not aware of any.

[21] Although individual parameter estimates for oil revenues vary from one method to another, they are always strongly significant.

indicate that the null hypothesis is overwhelmingly rejected in the case of the official exchange rate: Nigerien livestock prices do not respond one for one to an overvaluation of the Nigerian currency. When the unofficial exchange rate is used, significance levels drop and a few animal categories experience a change of sign. But the bulk of the evidence continues to suggest that Nigerian inflation is not transmitted one for one to Nigerien livestock prices. The explanation probably is that Niger is a major supplier of livestock into Nigeria, and thus is able to influence domestic prices there.

Is the magnitude of demand shifts something to worry about? An increase in cereal output by 10% over the 1988 record harvest would only raise animal prices by 2%. But a drop in output like the one that hit the country in 1973 and 1984 would translate into a 6.6 to 7.0% drop in livestock prices. A 10% increase in Nigerien uranium revenue relative to its 1988 value would generate a 2.9% average increase in the price of small rumimants and cattle. A boom comparable to that of 1979 would raise all livestock prices by about 17 to 18%. A 10% increase in Nigerian oil revenues relative to 1988 would raise livestock prices in Niger by 2.1% for small ruminants and 2.5% for cattle. A rapid increase in oil revenues like the ones that occurred in 1979 and 1986 would raise animal prices by 19 to 22%. Only horses and chicken would be somewhat spared because they are less exported: their prices would rise by only 10%. Comparing these values to the effects of weather leads us to conclude that the prosperity of the Nigerien livestock economy is driven at least as much if not more by meat demand consideration than by supply shocks.

Conclusions

Livestock markets play an ambiguous role in the Sahel. On the one hand, market integration insulates livestock prices from local conditions, thereby enhancing the insurance value of animals and stabilizing returns to livestock production. On the other, it subjects livestock prices to large shocks affecting urban demand and exports. Using a large but spotty data set from Niger, we measured the effect of weather shocks and demand shifters on livestock prices. Results confirm that droughts are particularly damaging to the livestock economy. Although the influence of rainfall on livestock prices is shown to be large, it does not account for some of the price changes that have taken place in recent years. Results indeed suggest that urban and rural demand for meat in Niger and neighboring Nigeria exert a predominant influence on Nigerien livestock prices as well.

Long distance livestock trade thus add an important element of risk to the livelihood of Sahelian producers as livestock prices are affected by the vagaries of primary commodity cycles and their effect on regional economies. This element of risk is perhaps uncorrelated with weather risk, but it can be devastating if a decrease in demand takes place after several years of drought, as happened in 1984. Although livestock prices *per se* are not useful indicators of impending famines, our results suggest that determinants of aggregate demand for livestock products help predict entitlement failures and should be incorporated in early warning systems.

Bibliography

Binswanger, H. P. and McIntire, J., ‘‘Behavioral and Material Determinants of Production Relations in Land-Abundant Tropical Agriculture,’’ *Econ. Dev. Cult. Change*, 36(1): 73-99, Oct. 1987.

Blough, S. R., *Spurious Regressions, with AR(1) Correction and Unit Root Pretest*, John Hopkins University, Baltimore, 1992. (mimeograph).

Brockwell, P. J. and Davis, R. A., *Time Series: Theory and Methods*, Springer-Verlag, New York, 1991.

Czukas, K., Fafchamps, M., and Udry, C., *Drought and Saving in West Africa: Are Livestock a Buffer Stock?*, Department of Economics, Northwestern University, Evanston, May 1995. (mimeograph).

Deaton, A., ‘‘Household Saving in LDCs: Credit Markets, Insurance and Welfare,’’ *Scand. J. Econ.*, 94(2): 253-273, 1992.

Deaton, A., ‘‘Saving and Income Smoothing in Cote d’Ivoire,’’ *J. African Economies*, 1(1): 1-24, March 1992.

de Leeuw, P. N. and de Haan, C., ‘‘A Proposal for Pastoral Development in the Republic of Niger,’’ *Pastoral Systems Research in Sub-Saharan Africa*, ILCA (ed.), Addis Ababa, 1983.

Dickey, D. A. and Fuller, W. A., ‘‘Autoregressive Time Series With a Unit Root,’’ *J. Amer. Statistical Assoc.*, 74(366): 427-431, June 1979.

Eddy, E., *Labor and Land Use on Mixed Farms in the Pastoral Zone of Niger*, University of Michigan, 1979. Livestock Production and Marketing in the Entente States of West Africa, Monograph No. 3.

Ellsworth, L. and Shapiro, K., ‘‘Seasonality in Burkina Faso Grain Marketing: Farmer Strategies and Government Policy,’’ *Seasonal Variability in Third World Agriculture*, IFPRI, Baltimore, 1989.

Engle, R. F. and Yoo, B. S., ‘‘Forecasting and Testing in Co-Integrated Systems,’’ *J. Econometrics*, 35: 143-159, 1987.

Engle, R. F. and Granger, C. W., ‘‘Co-Integration and Error Correction: Representation, Estimation, and Testing,’’ *Econometrica*, 55(2): 252-276, March 1987.

Fafchamps, M., *The Tragedy of the Commons, Cycles, and Sustainability*, Stanford, November 1993. (mimeograph).

Fafchamps, M. and Gavian, S., *The Spatial Integration of Livestock Markets in Niger*, Food Research Institute, Stanford, July 1995. (mimeograph).

Granger, C. W., ‘‘Investigating Causal Relations by Econometric Models and Cross-Spectral Methods,’’ *Econometrica*, 37(3): 424-438, July 1969.

Granger, C. and Newbold, P., ‘‘Spurious Regressions in Economics,’’ *J. Econometrics,* 2: 111-120, 1974.

Hamilton, J. D., *Time Series Analysis*, Princeton University Press, Princeton, N.J., 1994.

Im, K. S., Pesaran, M. H., and Shin, Y., *Testing for Unit Roots in Heterogeneous Panels*, University of Cambridge, Cambridge, July 1996. (mimeograph).

International Monetary Fund, *International Financial Statistics Yearbook*, Washington, D.C., 1992.

Jabara, C. L., *Structural Adjustment and Stabilization in Niger: Macroeconomic Consequences and Social Adjustment*, Cornell Food and Nutrition Program, Monograph 11, Ithaca, 1991.

Jarvis, L. and Erickson, R., ‘‘Livestock Herds, Overgrazing and Range Degradation in Zimbabwe: How and Why Do the Herds Keep Growing?,’’ *African Livestock Policy Analysis Network*, International Livestock Center for Africa, Addis Ababa, March 1986. Network Paper No. 9.

Jarvis, L., ‘‘Overgrazing and Range Degradation in Africa: Is There Need and Scope for Government Control of Livestock Numbers?,’’ *East Africa Econ. Rev.*, p. 95-116, Nairobi, 1993.

Jarvis, L. S., ‘‘Cattle as Capital Goods and Ranchers as Portfolio Managers: An Application to the Argentine Cattle Sector,’’ *J. Polit. Econ.*, 82 (3): 489-520, 1974.

Kimball, M. S., ‘‘Precautionary Savings in the Small and in the Large,’’ *Econometrica*, 58(1): 53-73, January 1990.

Levin, A. and Lin, C., *Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties*, University of California, San Diego, San Diego, 1993. (mimeograph).

Livingstone, I., ‘‘Livestock Management and "Overgrazing" Among Pastoralists,’’ *Ambio*, 20 (2): 80-85, April 1991.

Makinen, M. and Ariza-Nino, E. J., *The Market for Livestock from the Central Niger Zone*, Niger Range and Livestock Project, Center for Research on Economic Development, University of Michigan for USAID, Ann Arbor, March 1982.

Perrier, G. K., *Limiting Livestock Pressure on Public Rangeland in Niger*, Pastoral Development Network, February 1986.

Quah, D., ‘‘Exploiting Cross-Section Variations for Unit Root Inference in Dynamic Data,’’ *Economic Letters*, 44: 9-19, 1994.

Reardon, T., Matlon, P., and Delgado, C., ‘‘Coping With Household Level Food Insecurity in Drought-Affected Areas of Burkina Faso,’’ *World Development*, 16, No. 9, 1988.

République du Niger, *Bulletin Statistique Trimestriel*, Direction des Statistiques et de la Démographie, Ministère du Plan et de la Planification Régionale, Niamey, 1991a.

République du Niger, *Les Prix à la Consommation*, Direction des Statistiques et de la Démographie, Ministère du Plan et de la Planification Régionale, Niamey, 1991b.

République du Niger, *Annuaire Statistique "Séries Longues"*, Direction de la Statistique et de la Démographie, Ministère du Plan, Niamey, 1991c.

Rosen, S., ‘‘Dynamic Animal Economics,’’ *Amer. J. Agric. Econ.*, 69(3): 547-557, August 1987.

Rosen, S., Murphy, K. M., and Scheinkman, J. A., ‘‘Cattle Cycles,’’ *J. Polit. Econ.*, 102(3): 468-492, June 1994.

Rosenzweig, M. R. and Wolpin, K. I., ‘‘Credit Market Constraints, Consumption Smoothing, and the Accumulation of Durable Production Assets in Low-Income Countries: Investments in Bullocks in India,’’ *J. Polit. Econ.*, 101(2): 223-244, 1993.

Sandford, S., *Management of Pastoral Development in the Third World*, John Wiley and Sons, New York, 1983.

SAS Institute, *SAS/ETS User's Guide*, SAS Institute Inc., Cary, NC, 1990.

Schimmelpfennig, D. and Thirtle, C., ‘‘Cointegration, and Causality: Exploring the Relationship Between Agricultural R&D and Productivity,’’ *J. Agricultural Econ.*, 54(2): 220-231, 1994.

SEDES, *Etude du Secteur Agricole du Niger - Bilan Diagnostic Phase 1*, SEDES, Paris, September 1987.

Sen, A., *Poverty and famines*, Clarendon Press, Oxford, 1981.

Shapiro, K., *Livestock Production and Marketing in the Entente States of West Africa: Summary Report* , University of Michigan , Ann Harbor, 1979.

Sims, C. A., ‘‘Bayesian Skepticism on Unit Root Econometrics,’’ *J. Economic Dynamic and Control*, 12: 463-474, 1988.

Sims, C. A. and Uhlig, H., ‘‘Understanding Unit Rooters: A Helicopter Tour,’’ *Econometrica*, 59: 1591-1599, 1991.

Solod, A. E., ‘‘Rainfall Variability and Twareg Perceptions of Climate Impacts in Niger,’’ *Human Ecology*, 1990.

Staatz, J. M., *The Economics of Cattle and Meat Marketing in the Ivory Coast*, University of Michigan, 1979. Livestock Production and Marketing in the Entente States of West Africa.

Trotter, B. W., *Applying Price Analysis to Marketing Systems: Methods and Examples From the Indonesian Rice Market*, Natural Resource Institute, London, December 1991. (mimeograph).

Webb, P., Braun, J. v., and Yohannes, Y., *Famine in Ethiopia: Policy Implications of Coping Failure at National and Household Levels*, IFPRI, Washington, D.C., 1992. Research Report.

Zeldes, S. P., ‘‘Optimal Consumption With Stochastic Income: Deviations from Certainty Equivalence,’’ *Quarterly J. Econ.*, 104(2): 275-298, May 1989.

Table 1. Testing for Stationarity

Livestock prices:	In levels		In deviation from national average	
	Average ADF test	Standardized t-bar test	Average ADF test	Standardized t-bar test
A. Small Ruminants				
Ewe	-2.30	-5.56 **	-3.20	-11.91 **
Ram	-2.29	-5.48 **	-3.18	-11.82 **
Castrated Ram	-2.08	-3.98 **	-2.78	-8.84 **
Female Goat	-2.41	-6.30 **	-3.21	-11.82 **
Male Goat	-2.37	-6.03 **	-2.90	-9.83 **
Castrated Goat	-2.23	-4.99 **	-3.13	-11.29 **
B. Cattle				
Bull	-1.92	-2.87 **	-2.80	-8.96 **
Young Ox	-1.52	-0.04	-2.34	-5.79 **
Fattened Ox	-1.63	-0.80	-2.57	-7.38 **
Milch Cow	-1.91	-2.80 **	-2.99	-10.28 **
Heifer	-1.72	-1.44	-2.68	-8.14 **
Dry Cow	-1.39	0.82	-2.33	-5.68 **
C. Other				
Camel	-1.91	-2.81 **	-2.85	-9.45 **
Horse	-1.63	-0.79	-2.59	-7.38 **
Chicken	-1.77	-1.81 *	-2.64	-7.98 **
Rainfall:	-7.88	-45.01 **	-8.19	-47.20 **

All prices in levels. Rainfall is in deviation from long-term average. Similar results obtained using prices in logs. N=36, 37 or 38, depending on data availability. Number of lags in integrating equation p=3. Standardized t-bar test obtained using formula 3.28 in Im, Pesaran and Shin (1996). Similar results obtained using their formula 3.23. 5% critical value = -1.65; 1% critical value = -2.33. ** (*) means that the null hypothesis that the series is I(1) is rejected at the 1% (5%) level.

Table 2. Testing for Cointegration

A. Small Ruminants	Average ADF t-test	Standardized t-bar test	Pooled ADF t-tests	Autocorrelation coefficient	Standard error
Ewe	-3.26	-12.34	-8.24	0.467	*0.011*
Ram	-3.28	-12.50	-10.21	0.484	*0.011*
Castrated Ram	-2.82	-9.14	-7.57	0.537	*0.012*
Female Goat	-3.36	-12.88	-8.84	0.520	*0.011*
Male Goat	-2.98	-10.34	-8.42	0.558	*0.011*
Castrated Goat	-3.22	-11.90	-9.76	0.521	*0.012*
B. Cattle					
Bull	-2.88	-9.51	-8.54	0.652	*0.010*
Young Ox	-2.52	-7.03	-7.19	0.651	*0.011*
Fattened Ox	-2.71	-8.34	-8.17	0.679	*0.010*
Milch Cow	-3.00	-10.34	-9.43	0.587	*0.011*
Heifer	-2.89	-9.64	-7.49	0.637	*0.010*
Dry Cow	-2.53	-7.11	-7.73	0.640	*0.011*
C. Other					
Camel	-2.95	-10.14	-9.82	0.573	*0.011*
Horse	-2.58	-7.37	-6.57	0.686	*0.011*
Chicken	-2.78	-8.97	-8.67	0.583	*0.011*

Cointegration test based on residuals from equation (2). Similar results obtained using prices in logs. N=36, 37 or 38, depending on data availability. Number of lags in integrating equation p=3. Standardized t-bar test obtained using formula 3.28 in Im, Pesaran and Shin (1996). Similar results obtained using their formula 3.23. 5% critical value = -1.65; 1% critical value = -2.33. Pooled ADF t-test obtained by estimating equation (3) on the pooled residuals from all districts. Autocorrelation coefficient obtained by maximum likelihood with Kalman filtering for missing variables. See text for details

Table 3. Likelihood Ratio Tests on Rainfall Variables

	(I)		(II)	
A. Small Ruminants				
Ewe	16.984		35.640	***
Ram	33.445	***	35.224	***
Castrated Ram	36.868	***	17.354	***
Female Goat	30.004	**	34.752	***
Male Goat	31.434	***	21.476	***
Castrated Goat	27.702	**	34.740	***
B. Cattle				
Steer	33.780	***	17.154	***
Young Ox	40.552	***	22.380	***
Fattened Ox	31.184	***	40.094	***
Milch Cow	51.460	***	42.838	***
Heifer	47.046	***	41.998	***
Dry Cow	71.278	***	26.620	***
C. Other				
Camel	32.778	***	25.876	***
Horse	20.524		19.940	***
Chicken	31.594	***	25.082	***

(I) Testing whether rainfall in neighboring districts matters. 15 restrictions. Critical Chi-square values are: 22.307* (10%); 24.996** (5%); 30.578*** (1%).

(II) Testing whether rainfall in own district matters. 5 restrictions. Critical Chi-square values are: 9.236* (10%); 11.071** (5%); 15.086*** (1%).

Table 4. Significance of Rainfall Variables

	District Rainfall					1st Neighbor's Rain					2nd Neighbor's Rain					3rd Neighbor's Rain				
A. Small Ruminants	**L1**	**L2**	**L3**	**L4**	**Dr.**	**L1**	**L2**	**L3**	**L4**	**Dr.**	**L1**	**L2**	**L3**	**L4**	**Dr.**	**L1**	**L2**	**L3**	**L4**	**Dr.**
Ewe			--	--	++					++										
Ram		-	--	--	++	--		--		++			--		+	--	-			++
Castrated Ram			--	--	++	--	--	--	--	++								--		
Female Goat		++		--	++									-						
Male Goat			--	--	+								--	--						
Castrated Goat		++	--	--	++					+		++				--				
B. Cattle																				
Bull	-			--	++			-	-	++	-			--						
Young Ox				--	++			-		++				--			+	+		
Fattened Ox				--	++	-	--	--	-	++				-						
Milch Cow	--			--	++	--		--	--	++			++							
Heifer		++	++		++				-	++				-	+					
Dry Cow		++		--	++	-		--	--	++				--	+	+	++	+		
C. Other																				
Camel		+		--	++				-				--	--	++		+			
Horse				--								++	+			-				
Chicken		-	--	--	++	-	--	--	--	++				-	+					

L1 = rainfall over the last six months in deviation from the mean. L2 = L1 lagged six months. L3 = L1 lagged 12 mont
L4 = L1 lagged 18 months. Dr. = drought indicator, i.e., rainfall over last 2 years in deviation from the mean, truncate
above zero (see text for details).

++ Coefficient positive and significant at the 5% level.
\+ Coefficient positive and significant at the 10% level.
-- Coefficient negative and significant at the 5% level.
\- Coefficient negative and significant at the 10% level.

Table 5. Testing for Cointegration In the Presence of Demand Shifters

	Model (1)		Model (2)		Model (3)		Model (4)	
A. Small Ruminants	**Average ADF test**	**Stand. t-bar test**	**Average ADF test**	**Stand. t-bar test**	**Average ADF test**	**Stand. t-bar test**	**Average ADF test**	**Stand. t-bar test**
Ewe	-2.93	-10.05	-2.94	-10.12	-2.95	-10.13	-2.95	-10.13
Ram	-3.00	-10.53	-2.98	-10.40	-3.01	-10.62	-3.01	-10.57
Castrated Ram	-2.62	-7.70	-2.61	-7.66	-2.63	-7.78	-2.63	-7.78
Female Goat	-2.92	-9.82	-2.93	-9.90	-2.94	-9.96	-2.93	-9.89
Male Goat	-2.66	-8.15	-2.68	-8.25	-2.67	-8.19	-2.67	-8.21
Castrated Goat	-2.89	-9.61	-2.87	-9.49	-2.91	-9.74	-2.90	-9.69
B. Cattle								
Bull	-2.61	-7.69	-2.72	-8.45	-2.82	-9.15	-2.70	-8.28
Young Ox	-2.11	-4.19	-2.12	-4.24	-2.11	-4.20	-2.10	-4.13
Fattened Ox	-2.27	-5.31	-2.30	-5.46	-2.27	-5.25	-2.27	-5.29
Milch Cow	-2.69	-8.18	-2.70	-8.27	-2.71	-8.37	-2.70	-8.29
Heifer	-2.46	-6.61	-2.50	-6.87	-2.48	-6.76	-2.48	-6.73
Dry Cow	-2.19	-4.76	-2.20	-4.79	-2.19	-4.71	-2.19	-4.71
C. Other								
Camel	-2.65	-8.03	-2.65	-8.04	-2.65	-8.02	-2.63	-7.89
Horse	-2.36	-5.83	-2.35	-5.80	-2.33	-5.66	-2.34	-5.70
Chicken	-2.50	-6.99	-2.49	-6.91	-2.49	-6.94	-2.49	-6.88

Cointegration test based on residuals from equation (6). Models (1) to (4) correspond to different specifications of the exchange rate; see text for details. Similar results obtained using prices in logs. N=36, 37 or 38, depending on data availability. Number of lags in integrating equation p=3. Standardized t-bar test obtained using formula 3.28 in Im, Pesaran and Shin (1996). Similar results obtained using their formula 3.23. 5% critical value = -1.65; 1% critical value = -2.33.

Table 6. Autocorrelation Coefficients in Equation (6)

A. Small Ruminants	Model (1)		Model (2)		Model (3)		Model (4)	
Ewe	0.555	*0.011*	0.554	*0.011*	0.549	*0.011*	0.554	*0.011*
Ram	0.547	*0.011*	0.549	*0.011*	0.544	*0.011*	0.537	*0.011*
Castrated Ram	0.594	*0.012*	0.596	*0.011*	0.589	*0.012*	0.590	*0.012*
Female Goat	0.597	*0.010*	0.595	*0.010*	0.591	*0.010*	0.595	*0.103*
Male Goat	0.613	*0.010*	0.613	*0.010*	0.610	*0.010*	0.614	*0.010*
Castrated Goat	0.584	*0.011*	0.587	*0.011*	0.578	*0.011*	0.583	*0.011*
B. Cattle								
Bull	0.720	*0.009*	0.719	*0.009*	0.719	*0.009*	0.721	*0.009*
Young Ox	0.728	*0.009*	0.724	*0.009*	0.726	*0.010*	0.727	*0.010*
Fattened Ox	0.752	*0.009*	0.750	*0.009*	0.751	*0.009*	0.753	*0.009*
Milch Cow	0.680	*0.010*	0.677	*0.010*	0.674	*0.010*	0.678	*0.010*
Heifer	0.720	*0.010*	0.717	*0.010*	0.718	*0.010*	0.721	*0.010*
Dry Cow	0.730	*0.010*	0.726	*0.010*	0.727	*0.010*	0.729	*0.010*
C. Other								
Camel	0.670	*0.010*	0.669	*0.010*	0.669	*0.010*	0.671	*0.010*
Horse	0.725	*0.010*	0.727	*0.010*	0.726	*0.010*	0.726	*0.010*
Chicken	0.648	*0.010*	0.648	*0.010*	0.645	*0.010*	0.645	*0.010*

Maximum likelihood estimates of the autocorrelation coefficient of the residuals from equation (6). Standard errors giver in italics. Models (1) to (4) correspond to different specifications of the exchange rate; see text for details.

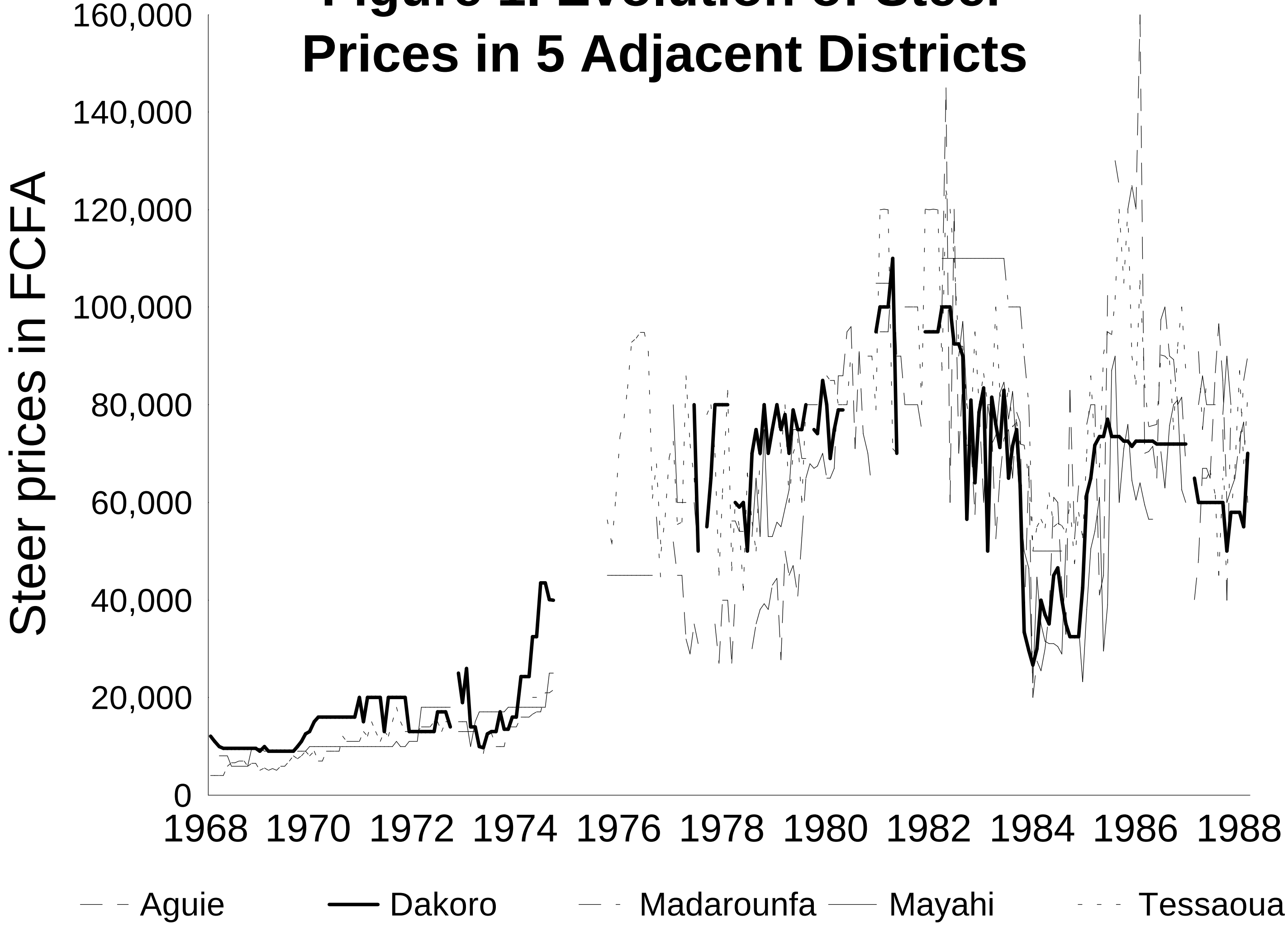
Table 7. Significance of Demand Shifter Variables

		Cereal Output	Nigerien Uranium Revenue	Nigerian Oil Revenue	Exchange Rate Disequilibrium				Tabaski dummies: Current Month	1 Month Ahead	2 Months Ahead
		(All)	(All)	(All)	(1)	(2)	(3)	(4)	(All)	(All)	(All)
A. Small Ruminants											
Ewe	Level	++	++	++			--	--		++	
	Logs	++	++	++			--	--	+,++	++	
Ram	Level	++	++	++	++	++	--		++	++	++
	Logs	++	++	++	++	++	--	--	++	++	++
Castrated Ram	Level	++	++	++	+	++	--	+	++	++	0,++
	Logs	++	++	++		++	--		++	++	
Female Goat	Level	++,+	++	++			--	--	++		
	Logs	++	++	++			--	--	++		
Male Goat	Level	++	++	++		++	--	--	++	++	
	Logs	++	++	++			--	--	++	++	
Castrated Goat	Level	++	++	++	++	++	--		++	++	
	Logs	++	++	++			--	--	++	++	
B. Cattle											
Bull	Level	++	++	++		++	--				
	Logs	++	++	++			--	--			
Young Ox	Level	++	++	++			--	--			
	Logs	++	++	++			--	--			
Fattened Ox	Level	++	++	++		++	--				
	Logs	++	++	++		++	--	-			
Milch Cow	Level	++	++	++			--	--	--		
	Logs	++	++	++			--	--	--		
Heifer	Level	++	++	++	+	++	--				
	Logs	++	++	++		++	--	--			
Dry Cow	Level	++	++	++		++	--				
	Logs	++	++	++			--	--			
C. Other											
Camel	Level	++	++	++	+	++	--				
	Logs	++	++	++		++	--				--,0
Horse	Level	++	++	++		++	--	++			
	Logs	++	++	++		++	--	+			--,0
Chicken	Level	++	++	++	++	++	--	++			--,0
	Logs	++	++	++	++	++	--				

++' Coefficient positive and significant at the 5% level.
\+ Coefficient positive and significant at the 10% le
-- Coefficient negative and significant at the 5% level.
\- Coefficient negative and significant at the 10% level.

(1) Oil revenue deflated by Nigerian GDP deflator. Exchange rate disequilibrium variable constructed using the official exchange rate.
(2) Oil revenue deflated by Nigerian GDP deflator. Exchange rate disequilibrium variable constructed using the unofficial exchange rate.
(3) Oil revenue turned into CFA using the official exchange rate and deflated by Niamey African CPI. Exchange rate disequilibrium variable constructed using the official exchange rate.
(4) Oil revenue turned into CFA using the unofficial exchange rate and deflated by Niamey African CPI. Exchange rate disequilibrium variable constructed using the unofficial exchange rate.
(All) = (1) + (2) + (3) + (4)

Figure 1. Evolution of Steer Prices in 5 Adjacent Districts



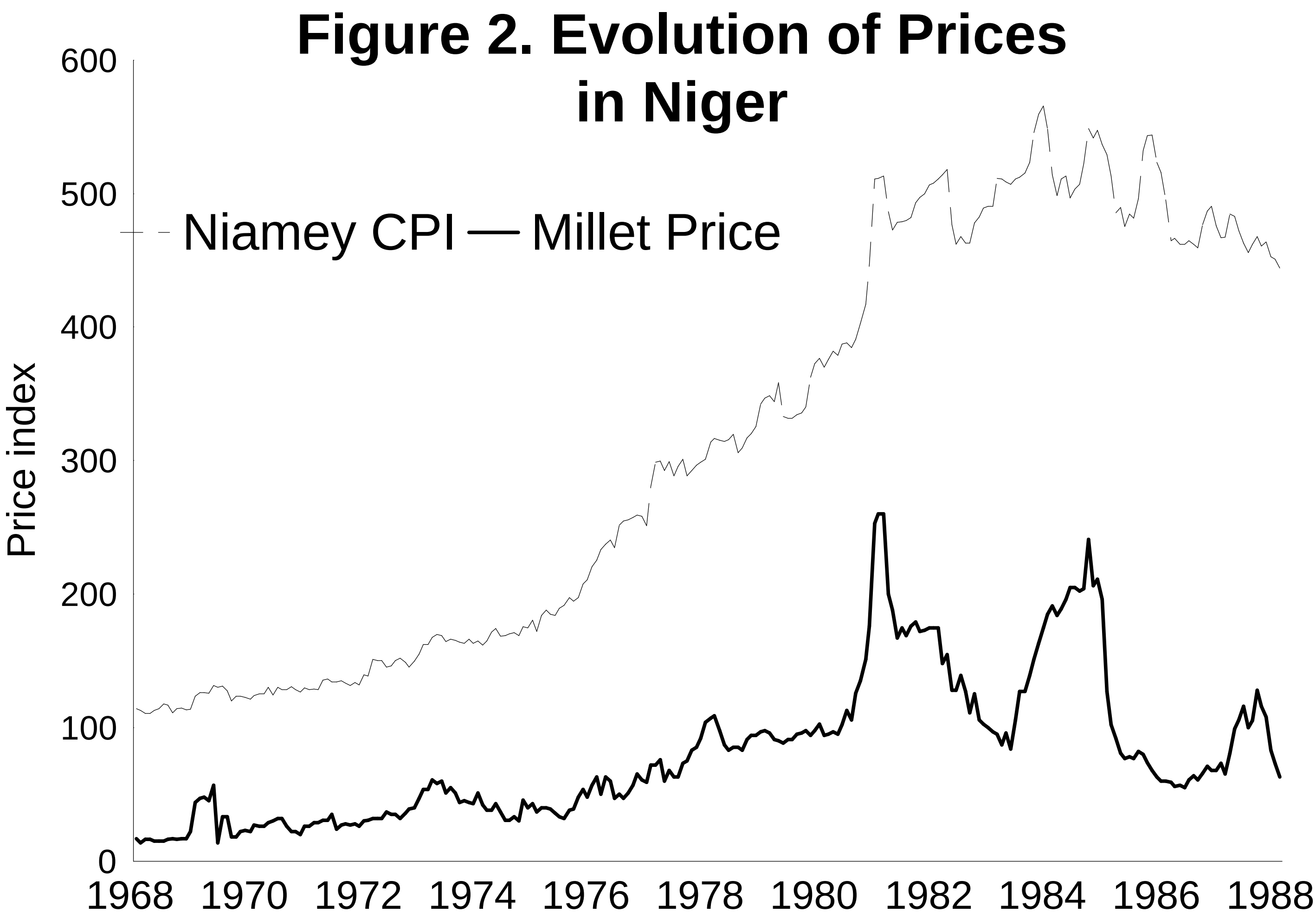


Figure 2. Evolution of Prices
in Niger
Niamey CPI
Millet Price
Price index
600
500
400
300
200
100
0
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988

Figure 3. Evolution of Rainfall in Selected Districts

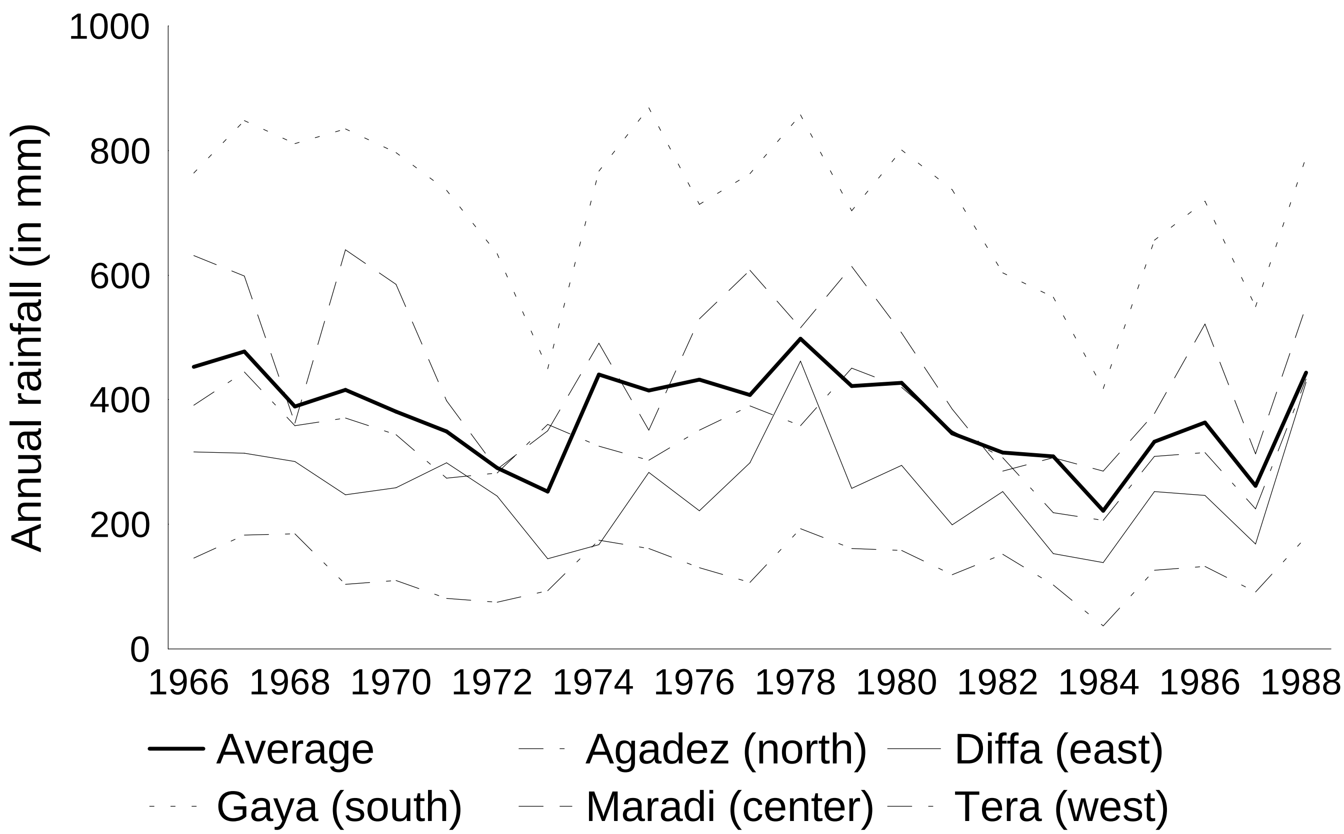


Figure 4. Evolution of Cattle Prices

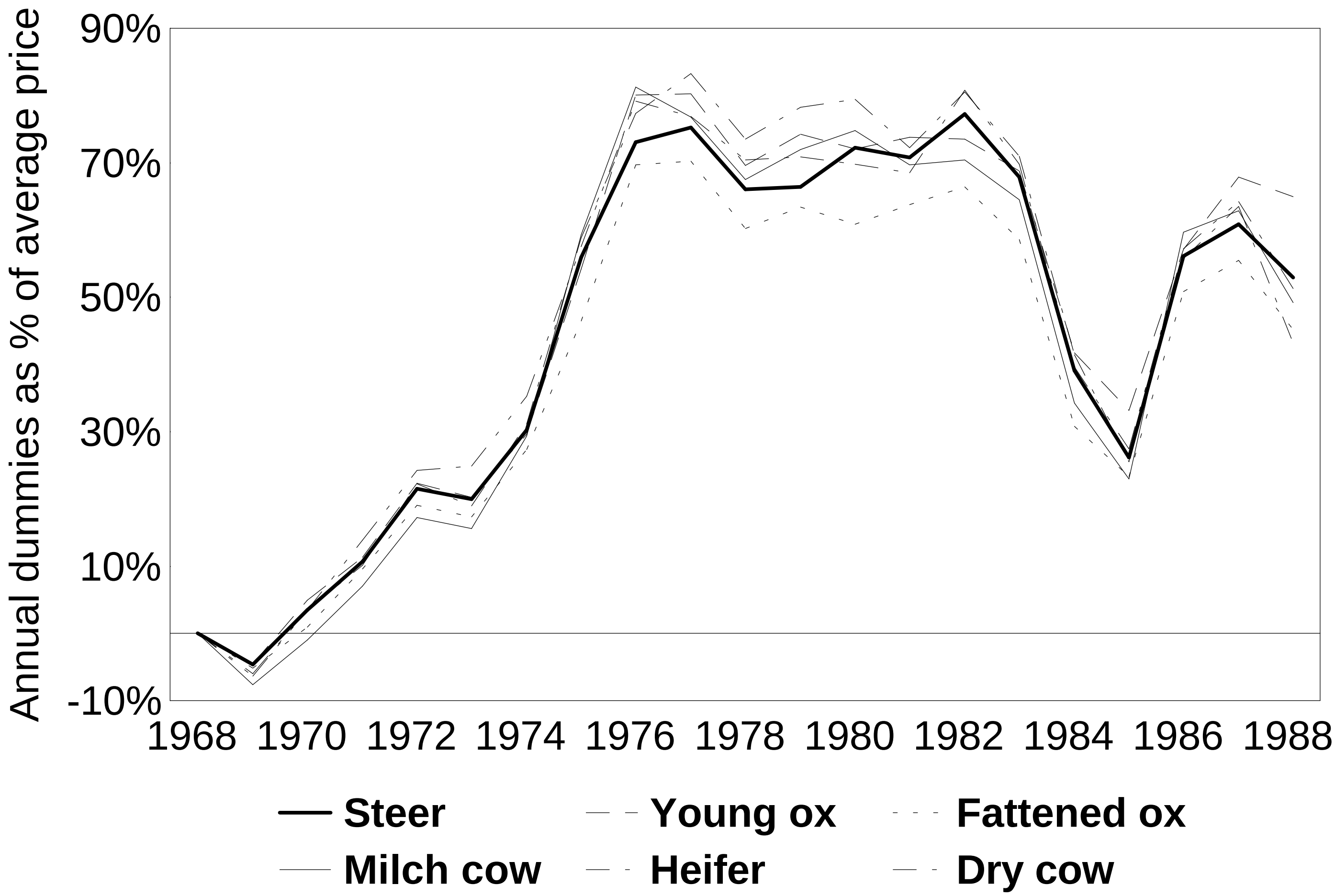
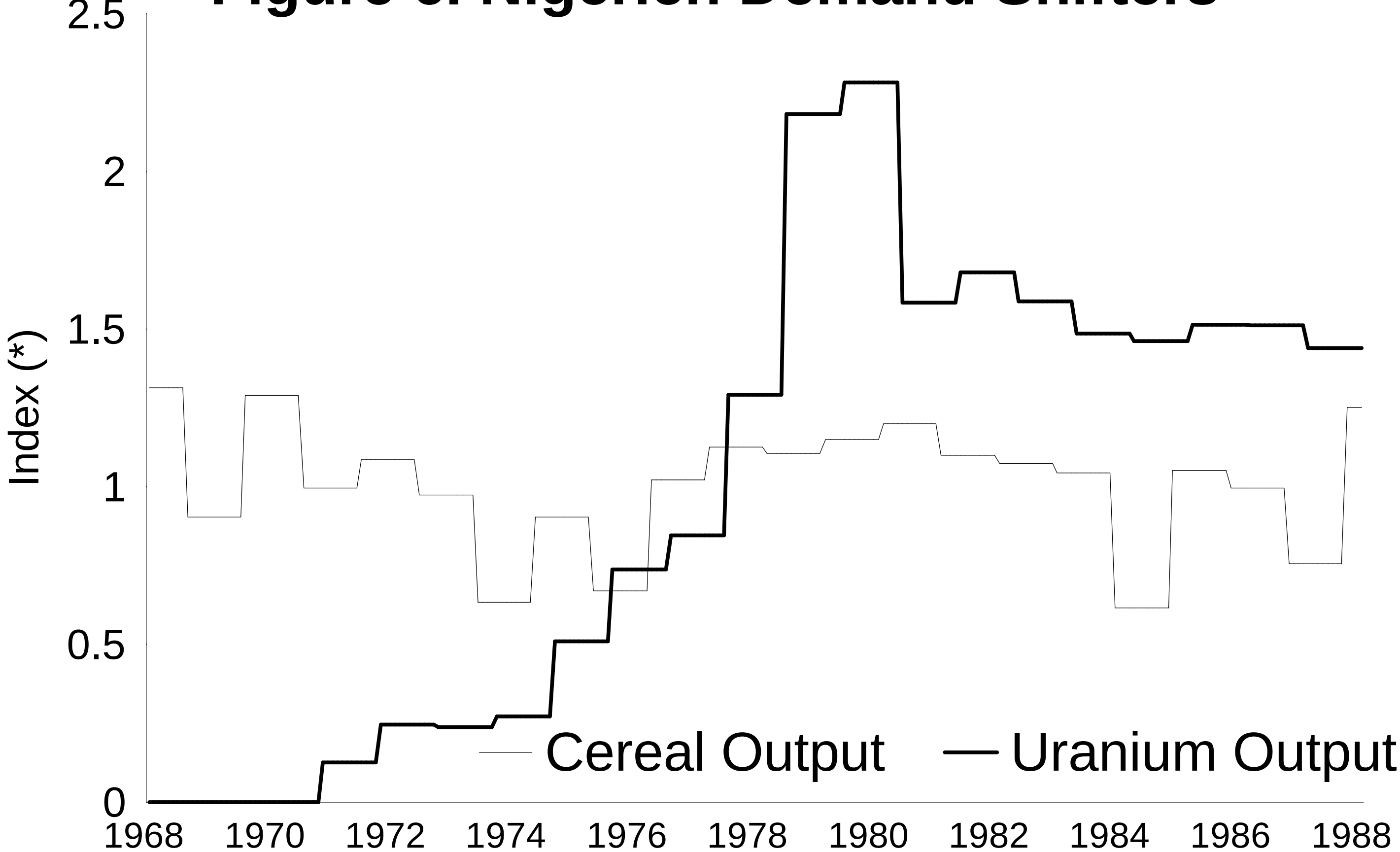


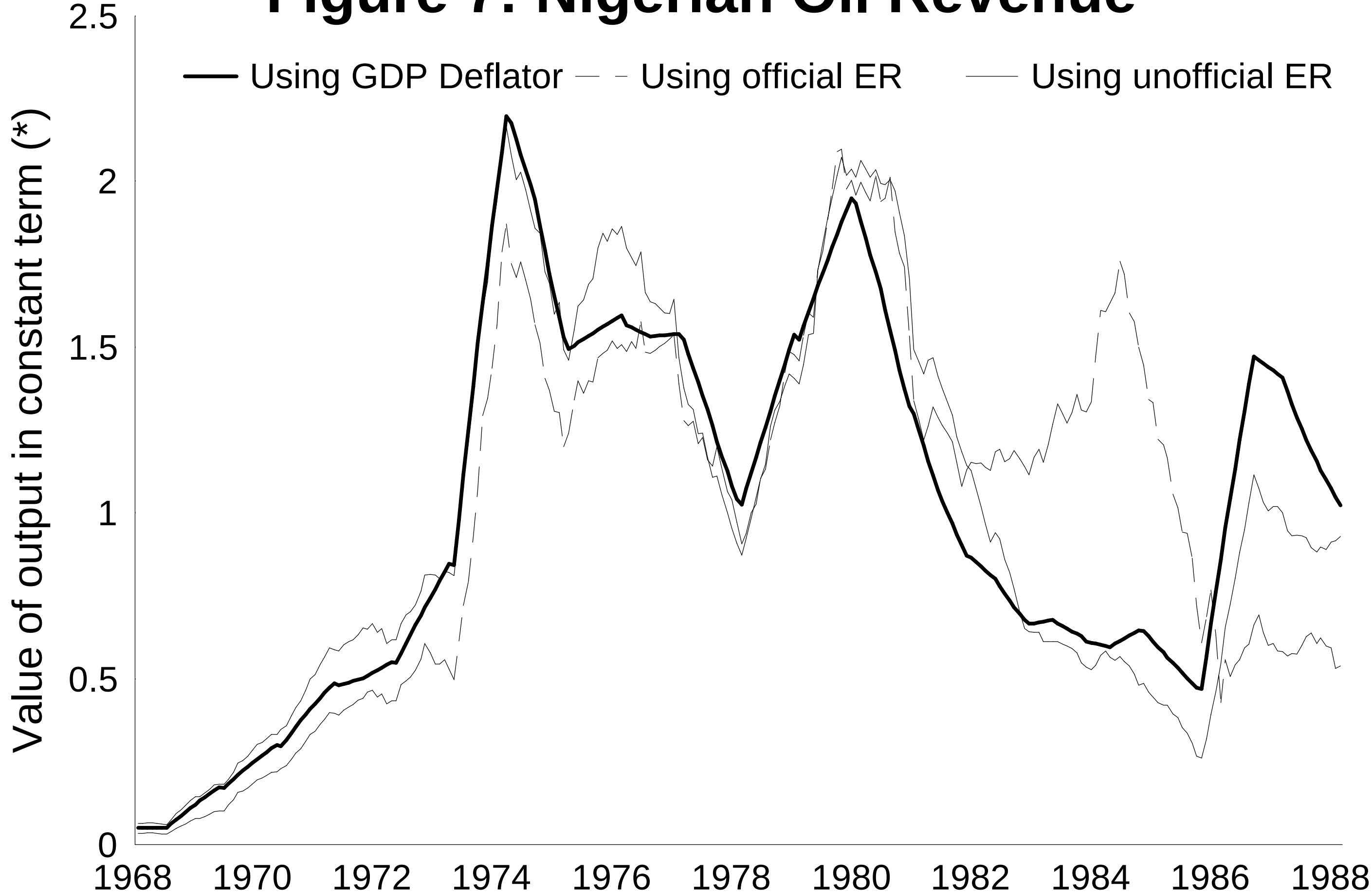
Figure 5. Seasonal Changes in Cattle Prices

Figure 6. Nigerien Demand Shifters



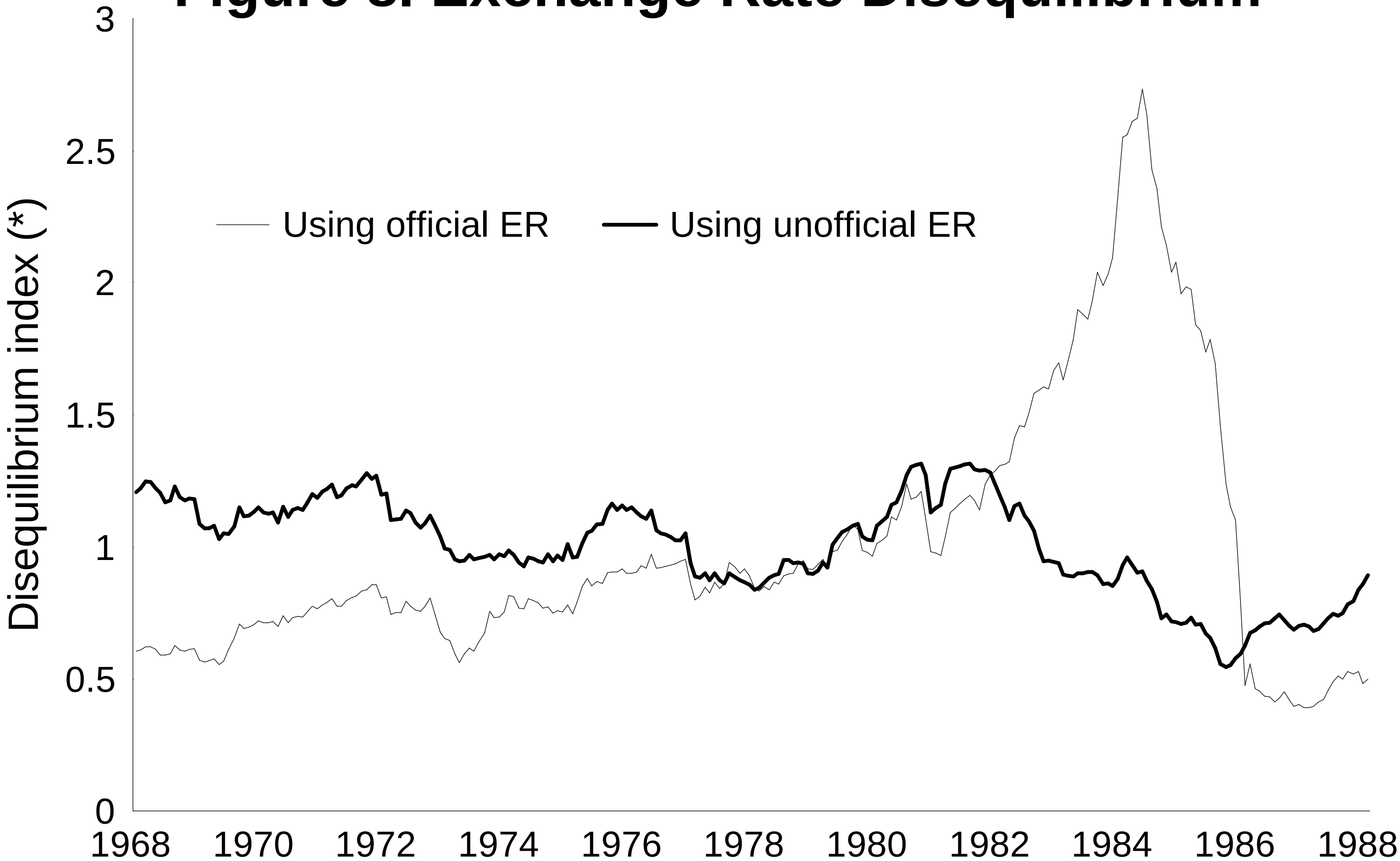
(*) Variables have been divided by their average to facilitate comparison.

Figure 7: Nigerian Oil Revenue



(*) Variables have been divided by their average to facilitate comparison.

Figure 8. Exchange Rate Disequilibrium



(*) Variables have been divided by their average to facilitate comparison.