The Spatial Integration of Livestock Markets in Niger

Marcel Fafchamps † *and Sarah Gavian* ††

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Abstract

Livestock makes an important contribution to the livelihood of Sahelian farmers and herders and is a source of self-insurance against income shocks. By allocating livestock efficiently over space, spatial market integration should foster a sustainable use of pasture resources. It is also expected to favor the sharing of risk across regions by smoothing idiosyncratic price variations. Using monthly livestock price data from Niger, we show that livestock markets are poorly integrated. Prices are seldom co-integrated, short-term integration is largely absent and there is evidence of market segmentation. Large price differentials occasionally persist between adjacent areas for long periods of time. A parity bounds approach indicates that one has to assume high transportation costs and quality variations to reconcile the data with efficient spatial arbitrage. These results confirm descriptive studies that have emphasized regional segmentation in West African livestock trade.

† Assistant Professor, Food Research Institute, Stanford University, Stanford, CA 94305-6084. †† Agricultural Economist, International Livestock Center for Africa, P.O.Box 5689, Addis Ababa, Ethiopia.

Livestock production is a major industry in semi-arid Africa in general, and in the Sahel in particular. It is also one of the Sahel's main export, directed primarily toward coastal areas of West Africa (e.g., Staatz (1979), Eddy (1979), Fafchamps and Gavian (1995)). As the recent droughts of 1973 and 1984 have amply demonstrated, however, the livestock industry is vulnerable to local pasture availability and weather shocks. By allocating livestock more efficiently over space, market integration should favor a better use of scarce pasture resources. Indeed, to the extent that producers react to local pasture availability by selling or buying animals, price differentials between regions should signal differences in returns to livestock (e.g., Sandford (1983), Livingstone (1986), Fafchamps (1993), Fafchamps and Gavian (1995)). Spatial arbitrage is therefore expected to reduce excessive pressure on the environment by helping livestock move out of stressed areas. Studying the geographical integration of livestock markets should shed light on the optimal and sustainable use of one of the Sahel's most critical natural resources, pasture.

Market integration is also critical for the prevention of entitlement failures. Sahelian farmers and pastoralists rely on the accumulation of livestock not only as a source of income but also as a form of precautionary savings (e.g., Sandford (1983), Binswanger and McIntire (1987), Reardon, Matlon and Delgado (1988), Ellsworth and Shapiro (1989), Czukas, Fafchamps and Udry (1995)). To provide protection against local weather shocks, this strategy requires livestock prices not to drop dramatically when large numbers of livestock are presented for sale on local markets. Otherwise the collapse in the livestock-grain terms of trade leads to an entitlement failure and results in famine (e.g., Sen (1981), Reardon, Matlon and Delgado (1988), Webb, Braun and Yohannes (1992)). The geographical integration of markets determines the extent to which weather risk is shared over space and thus the insurance value of livestock (Fafchamps (1992)).

To throw new light on these issues, we study in this paper the integration of livestock markets in a representative Sahelian country, Niger. The basis for our analysis is price data on 15 animal categories collected monthly in 38 districts over a period of 21 years. The questionable quality of the data and the high proportion of missing observations are somewhat compensated by the sheer number of data points: 87,000 in total. No reliable data exist on stocks, consumption, exports, quantities transacted, transportation costs, or movements of animals between districts in Niger (SEDES (1987)). Livestock production and marketing have, however, been described in micro or sectoral studies, e.g., Eddy (1979), Bellot (1982), and Makinen and Ariza-Nino (1982).

We study price variability over space by testing whether Nigerien livestock prices are spatially integrated. To partially compensate for the weaknesses of the data, we do not rely on a single test of market integration but instead compute and compare a variety of approaches that have been proposed in the literature: co-integration; Granger-causality; and Ravallion's (1986) model of market integration. We also econometrically estimate a parity bounds model suggested by Baulch (1994). Results indicate that the geographical integration of livestock markets in Niger is low, that prices in different districts often fail to co-move, and that they frequently exceed their parity bounds. We nevertheless find a weak yet significant relationship between indicators of market integration and the proximity between markets. Estimated price differentials between districts are somewhat consistent with the catchment areas described in Makinen and Ariza-Nino (1982) and Bellot (1982). But districts located 'off the beaten track' appear impervious to short-term movements in prices that spread along major trade routes. The geographical integration of livestock markets is imperfect and the spatial pooling of risk not fully achieved.

Section 1. Livestock Markets in Niger

Although it widely acknowledged that livestock production and marketing are important activities in Niger, quantitative evidence is rare. The reason partly lies in the government's efforts to tax imports and exports of livestock and in the ensuing secrecy that generally surrounds livestock transactions in Niger. It is, for instance, estimated that as much as 80 to 90 percent of Nigerien[1] livestock exports are not declared and avoid taxation (e.g., Bellot (1982), Cook et al. (1988), Guillaumont and Guillaumont (1991), SEDES (1987)). At times, the Nigerien government has also tried to restrict movements of livestock to protect the perceived interests of local producers and consumers. These measures seem to have had little actual impact on livestock imports and exports, but they also fueled secrecy (e.g., SEDES (1987), Guillaumont and Guillaumont (1991), Cook et al. (1988)).

It is nevertheless possible to piece together a portrait of livestock trade in Niger by drawing from existing micro studies and descriptive evidence. Livestock production is estimated to constitute the major occupation of the 18 to 20 percent of the Nigerien population who are nomad pastoralists (see République Francaise (1966), Bellot (1982), p.10). In addition, it represents a major source of additional income for the rest of rural households (e.g., SEDES (1987), Bellot (1982), Eddy (1979)).

The literature typically distinguishes two categories of motives for holding lives-

[1] 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".

tock: income generation, and precautionary saving (e.g., Eddy (1979), Bellot (1982), République Francaise (1966), Czukas, Fafchamps and Udry (1995)). Presumably, producers who sell animals only in times of hardship tend to get a lower price that those who can afford to wait. Bellot (1982) provides evidence of persistent differences across ethnic groups in their motives for selling livestock, and links price differentials between regions to differences in ethnic settlement. Livestock prices are also affected by large scale weather shocks as animals that were accumulated in good times are massively sold (or lost) during droughts (e.g., Livingstone (1986), Fafchamps (1993), Fafchamps and Gavian (1995)).[2]

Livestock is the second Nigerien export after uranium (e.g., SEDES (1987), Guillaumont and Guillaumont (1991), Jabara (1991)). During the last decades, most livestock exports from Niger went to Nigeria, either directly or via Benin (e.g., SEDES (1987), Bellot (1982), Makinen and Ariza-Nino (1982)) and Sahelian livestock prices have been shown to respond to shifts in urban demand in coastal countries (e.g., Shapiro (1979), Fafchamps and Gavian (1995)). The principal entry points into Nigeria seem to follow major roads and rivers, even though animals typically are trekked (that is, walked) across the border to avoid detection by customs agents (e.g., SEDES (1987), Bellot (1982)). The reason is that animals are normally loaded onto trucks once inside Nigeria (e.g., Makinen and Ariza-Nino (1982)). According to Bellot (1982) and Makinen and Ariza-Nino (1982), large livestock imports from Mali transit through Niger on their way to Nigeria. Nigerien urban centers like Niamey, Maradi and Zinder, and mining towns like

[2] See nevertheless Czukas, Fafchamps and Udry (1995) for conflicting evidence. Gestation lags in livestock production can generate price cycles as well; see Jarvis (1974), and Rosen, Murphy and Scheinkman (1994) for evidence in other parts of the world.

Arlit (uranium) attract livestock for local consumption (e.g., SEDES (1987), Bellot (1982)).

Livestock trade is organized through networks of traders linked by strong personal, ethnic and family ties (e.g., Arnould (1985), Bellot (1982)).[3] The *dillam* (plur. *dillali)* is the name given to the key intermediary between producers and traders on local markets (e.g., Makinen and Ariza-Nino (1982), Bellot (1982)). Through him, prices are negotiated and enforcement of the contract is guaranteed. Traders organize and finance the transport of animals across the border, occasionally by truck, most usually by foot (e.g., Makinen and Ariza-Nino (1982), Bellot (1982), SEDES (1987), Staatz (1979)). The trader has a correspondent across the border, called *logeur* or host, who assists in the selling of livestock (e.g., Bellot (1982); see Staatz (1979) for a similar institution in Ivory Coast). The actual transport of the livestock is supervised by a trusted representative of the trader, called the *madougou* (e.g., Bellot (1982)).

Animals destined for export are not transferred from market to market within Niger but rather bundled in groups of 50 heads or more and shipped directly across the border. To minimize transaction costs, traders concentrate their purchases on active markets where large groups of livestock can be assembled for immediate shipment (e.g., Makinen and Ariza-Nino (1982), Bellot (1982), Arnould (1985), Staatz (1979)). Neighboring markets serve as collection points. The location of assembly markets may shift over time as parties try to avoid detection by tax collectors (e.g., Bellot (1982); personal communication).

[3] See Staatz (1979) for a similar description of livestock trade in Ivory Coast.

According to République Francaise (1966), 64 to 82 percent of animal sales by producers take place on local markets. The rest is sold to other herders. Bellot (1982) nevertheless reports observing that cattle smuggled from Mali were sold outside markets to avoid detection (pp.55-56). It unclear whether producers can decide to sell their animals in neighboring districts. Ethnic differences across regions and lack of acquaintance with local intermediaries may indeed discourage producers from selling in unfamiliar markets.

Little information is available regarding livestock marketing costs. Assuming that animals are trekked in groups of 80 heads, Bellot (1982) estimates that the costs of buying, transporting and selling livestock from Western Niger to Southern Nigeria varied between 4,000 to 6,500 CFA Francs in 1978 -- or roughly 10 percent of the producer price. Using these figures, he derives net margins for traders comprised between 50 and 60 percent. These margins appear excessive.[4] Arnould (1985) gives a more reasonable 17 percent estimate of the average net profit on current inventory for cereals, cloth and livestock dealers in the Zinder district, but does not detail marketing costs for livestock.

Previous analyzes of market integration in Niger have concluded that long distance trade is important but also that markets are not well integrated (e.g., Makinen and Ariza-Nino (1982)). Bellot (1982) reports persistent price differences between two neighboring districts equal to five times the estimated cost of transporting an animal all the way to Southern Nigeria. In a study of regional markets in the Zinder district, Arnould (1985) concludes that "there exists a regional marketing system in Zinder but the system is far from providing even geographical coverage, and a number of market subsystems are of

[4] Bellot may have underestimated weight loss and other hazards of the trip. See Staatz (1979) for Ivory Coast and Ansell (1971) (pp. 38-42) and McDonald (1978) (p.48) for Botswana.

limited allocative efficiency". These previous studies, however, are limited both in time and in geographical coverage. This article makes up for these shortcomings by analyzing in detail 21 years of monthly data in 38 districts of Niger.

We begin with a brief description of the data. We then continue with a conventional analysis of market integration, examining to what extent livestock prices co-move over time. In the last section we examine price differentials between districts and try to ascertain whether they are consistent with spatial arbitrage.

Section 2. The Data

The livestock price data used in this paper were collected on a monthly basis by the Nigerien Department of Animal Resources and Hydrology.[5] The data cover 35 districts or *arrondissements* and 3 urban centers -- the cities of Niamey, Maradi and Zinder -- from January 1968 to December 1988 (Figure 1). 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 such 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.[6]

The available data is illustrated in Figure 2 for six contiguous districts around the

[5] 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.

[6] 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.

city of Zinder. The reader will notice the dramatic drop in prices during the 1984 drought. The historical evolution of prices is discussed in Fafchamps and Gavian (1995). To correct for inflation and avoid spurious results, the livestock price data are divided by the Niamey African Consumer Price Index (République du Niger (1991a, 1991b)).

Section 3. Market Integration

We begin our investigation of market integration in Niger by examining whether livestock prices in geographically different locations co-move. Instead of relying on a single test, we combine a variety of approaches and look for convergence across methods. We first compute correlation coefficients for each pair of the 38 localities and each of the 15 categories of animals. Results are summarized in Table 1. Most correlation coefficients lie between .3 and .6, well below price correlation coefficients computed for other agricultural products in Third World countries (e.g., Jones (1968), Blyn (1973), Timmer (1974), Trotter (1991)), but somewhat higher than those reported for bulls by Arnould (1985).[7] Correlation coefficients are higher for cattle than for small ruminants. They are lowest between two districts lying deep into the Sahara desert -- Arlit and Bilma -- and the rest of Niger. These results are globally consistent with the hypothesis that vast distances and poor transport infrastructure lead to high transaction costs, thereby making arbitrage unprofitable and isolating markets (Timmer (1974), Faminow and Benson (1990)). This hypothesis is confirmed by regressing correlation coefficients on the distance between markets. The results are summarized in Table 1. In all cases, distance has a negative effect on price correlation and for thirteen animal categories out of

[7] Arnould's (1985) correlation coefficients are based on much shorter and less aggregated price series: 27 price observations at two-week intervals.

fifteen, the effect is significant. The effect of distance on price correlation is more pronounced for cattle than for small ruminants.

Many authors have found the use of correlation coefficients as a measure of market integration to be fraught with problems (e.g., Harriss (1979), Heytens (1986), Trotter (1991), Timmer (1974)). A second battery of tests is therefore undertaken. Co-integration tests are conducted on all pairs of regional price series for each of the fifteen animal categories (Engle and Granger (1987), Trotter (1991), Goodwin and Schroeder (1991), Palaskas and Harriss-White (1993), Alexander and Wyeth (1994)). The prices series are first tested for integration of degree zero. The following regression is estimated for each monthly price series in each district:

$$\Delta P_t = \alpha_0 + \alpha_1 P_{t-1} + \alpha_2 \Delta P_{t-1} + \alpha_3 \Delta P_{t-2} + \alpha_4 \Delta P_{t-3} + e_t \quad (1)$$

where P_t is the log of livestock price at time t and $\Delta P_t = P_t - P_{t-1}$. Only three lags can be used, otherwise too many observations are lost as a result of missing data points.

The average t-values for α_1 are reported in Table 2. Individual t-values have to be compared to the critical value for the Augmented Dickey-Fuller test (Dickey and Fuller (1979)). For a one percent confidence level and three lags, the critical value of the test lies between -3.56 and -3.46 depending on sample size (Engle and Yoo (1987)). Twenty-six of 570 regressions (4.6%) are below (more negative than) the critical value. The percentage of cases below the critical value is only slightly above the one percent confidence level. Since we have no reason to believe that the few price series below the critical value are structurally different from the others, we conclude that the price series as a whole are not stationary, i.e., that they are not integrated of degree zero.

Next we difference the above equation and repeat the unit root test on:

$$\Delta^2 P_t = \beta_0 + \beta_1 \Delta P_{t-1} + \beta_2 \Delta^2 P_{t-1} + \beta_3 \Delta^2 P_{t-2} + \beta_4 \Delta^2 P_{t-3} + e_t \quad (2)$$

where $\Delta^2 P_t = \Delta P_t - \Delta P_{t-1}$. The corresponding average t-values for β_1 are reported in Table 2. Out of 570 regressions, 539 (94.6%) are below (more negative than) the critical value of the Dickey-Fuller test for the one percent confidence interval. The price series are thus integrated of degree one.

To test for co-integration, residuals are obtained from regressing the price in district i, $P_{i,t}$ on the price in district j, $P_{j,t}$:

$$P_{i,t} = \gamma_0 + \gamma_1 P_{j,t} + e_t \quad (3)$$

The residuals are then tested for integration of degree zero:

$$\Delta \hat{e}_t = \kappa_0 + \kappa_1 \hat{e}_{t-1} + \Delta \hat{e}_{t-1} + \Delta \hat{e}_{t-2} + \Delta \hat{e}_{t-3} \quad (4)$$

If the t-values for κ_1 is greater than the critical value for the Augmented Dickey-Fuller test, residuals are integrated of degree zero and prices are co-integrated (Engle and Granger (1987)). Depending on sample size, the critical value for the five percent confidence interval of the Augmented Dickey-Fuller test ranges between -3.36 and -3.42 (Engle and Yoo (1987)). Table 3 shows the average percentage of times that prices in each district are found to be co-integrated with prices in other districts. The evidence suggests that Niger does not operate as a unified livestock market. Over extended periods of time, prices in any given district can drift apart from prices in most other districts.

To test whether market integration varies consistently across space, we follow the example of Goodwin and Schroeder (1991) and regress the co-integration test statistic on distance. Results are reported in Table 4. For 11 animal categories out of 15, the effect of distance on the co-integration statistic is significant at the 5% level. Neighboring markets are thus more likely to be co-integrated than distant ones. Closer inspection of the results nevertheless indicates that there are many exceptions to this rule (Table 5). While districts like Magaria, Mirriah, and Tera are co-integrated with many others, certain districts are hardly co-integrated at all. In fact, one fifth of the districts (117 cases out of 570) are not co-integrated with any other district for at least one animal category.

To check whether the country is split into distinct price zones, we draw a line on the map of Niger between districts that are co-integrated (Figure 3 for steer). The resulting web reveals that, except for isolated areas like Bilma and Nguigmi, no part of the country is independent from the others. East-west price relationships dominate, but a few key livestock markets like Arlit, Agadez, Tanout and Tahoua appear to link the north with the south. Taken together, these results suggest that, while livestock markets are integrated along long-distance trade routes, districts removed from these routes are only loosely connected to the system.

Next we try to assess whether price movements follow well defined paths, i.e. start around demand or production centers and then spread across the country. To do so, we test for Granger causality between each pair of price series (Granger (1969), Schimmelpfennig and Thirtle (1994)). We use an error correction model suggested by Trotter (1991) and estimate the following equation:

$$\Delta P_{i,t} = \lambda_0 + \lambda_1 P_{i,t-1} + \lambda_2 P_{j,t-1} + \lambda_3 \Delta P_{i,t-1} + \lambda_4 \Delta P_{j,t-1} \tag{5}$$

If price movements in location j precede price movements in location i, $\Delta P_{j,t-1}$ and $P_{j,t-1}$ should have a significant effect on $\Delta P_{i,t}$. To verify the existence of Granger-causality, an F-test is conducted on the null hypothesis that $\lambda_2 = \lambda_4 = 0$. Because $P_{j,t-1}$ is not stationary, the distribution of the F-test is non-standard (e.g., Sims, Stock and Watson (1990), Dercon (1995)). The F-test results reported here use standard significance tables and are thus overstated. Explicitly correcting for the bias in F-tests is beyond the scope of this paper, but the larger the reported significance is, the more likely it is that district j Granger-causes district i.[8] Due to the stochastic pattern of missing observations, only one lagged value of ΔP_j is used to avoid losing too many degrees of freedom. Since, as is often the case for Granger-causality tests in small samples, results are sensitive to the number of distributed lags that are used, results from equation (5) should be interpreted with care.

A summary of the results is presented in Table 3. Roughly one fourth of the district pairs are shown to display some form of Granger causality, a percentage which, as anticipated, is higher than that of co-integrated districts because of the upward bias in significance levels. We focus our analysis not on absolute F-test results but rather on differences among districts. We first verify whether districts that are further apart are less likely to influence each other and regress the significance of the Granger causality test on distance.[9] Results, presented in Table 4, are significant at the 5% level for 9 of the 15 animal categories. Markets located close-by are thus more likely to Granger-cause each other: price shocks spread more easily over short distances.

Next, we examine whether certain districts are more likely to Granger-cause or be Granger-caused by other districts (Table 5). Presumably, districts that Granger-cause more than they are Granger-caused are points from which price shocks spread to other markets. Results show that a handful of key markets, printed in boldface, are originating points for price shocks. They tend to be located upstream, close to where livestock is assembled for long distance treks. The district of Tilabery, for instance, which is shown to Granger-cause 53% of the districts for cattle prices, is also, according to Bellot (1982)

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[8] Dercon (1995) suggests replacing $P_{j,t-1}$ in equation (5) by a series which has been tested for stationarity. Because Dercon's procedure involves pre-testing, however, his test also has a non-standard distribution.

[9] Similar results were obtained using logs instead of levels.

and Makinen and Ariza-Nino (1982), a place where cattle coming from Mali enter Niger. Districts that are Granger-caused by others tend to be large downstream markets, possibly located at entry points into Nigeria -- e.g., Birni Nkonni, Matameye, Dosso and Dogondoutchi (e.g., Makinen and Ariza-Nino (1982)).

Results thus suggest that the difficulty or ease with which livestock traders assemble livestock for trekking affect prices at downstream trading points. Combined with our knowledge of trade pattern, these results also indicate that prices fluctuations are dominated by supply shocks that ripple downstream through the system. The spreading of price shocks over long distances seems to operate through a limited number of key markets that serve as central clearing houses for livestock trade. Large flows of animals between dispersed markets thus appear to transmit price shocks better than small flows between neighboring markets.

To complement the above evidence, we used a modified Ravallion test of market segmentation to verify whether prices in one location are not influenced at all by what happens elsewhere (Ravallion (1986), Trotter (1991), Faminow and Benson (1990)). We also take advantage of Ravallion's model to test for medium and short run integration. The following pair of equations is jointly estimated using Three Stage Least Squares:

$$\Delta P_{i,t} = \alpha_0 + \alpha_1 \Delta P_{j,t} + \alpha_2 P_{i,t-1} + \alpha_3 \Delta P_{j,t-1} + \alpha_4 R_{i,t} + \alpha_5 \Delta X_t + \alpha_6 \Delta V_t + \Delta T_t \quad (6a)$$

$$\Delta P_{j,t} = \beta_0 + \beta_1 \Delta P_{i,t} + \beta_2 P_{j,t-1} + \beta_3 \Delta P_{i,t-1} + \beta_4 R_{j,t} + \beta_5 \Delta X_t + \beta_6 \Delta V_t + \Delta T_t \quad (6b)$$

Because of missing observations, only one lag can be used for price differences. With more than one lag, too many observations are lost.

As suggested by Ravallion, we add variables to control for the possible effect of exogenous shock on livestock prices. Several supply and demand shifters are identified (see Fafchamps and Gavian (1995) for details). Rainfall is a major determinant of pasture availability and thus a factor influencing livestock productivity and supply. Rainfall data comes from meteorological station reports (Service Agro-Météorologique, Ministère des Transports et du Tourisme, République du Niger); they are averaged by district and their effect on livestock prices is captured by variable $R_{i,t}$ which stands for rainfall in district i at time t, deviated from its monthly district mean. Aggregate demand shifters are constructed as follows. The deflated value of oil output V_t controls for shifts in aggregate Nigerian demand for livestock. The value of Nigerian oil production is taken from International Monetary Fund (1992), and deflated by the Nigerian GDP deflator (International Monetary Fund, 1992). Tabaski is a Moslem festival widely celebrated in the Sahel, during which it is customary to sacrifice an animal, preferably a ram. T_t is a dummy variable taking the value of one if the Tabaski celebration falls in month t. Since Nigerian demand has an effect on livestock prices in Niger (e.g., SEDES (1987), Fafchamps and Gavian (1995)), we expect a devaluation of the Naira to depress Nigerien prices. To control for this effect, we include in equations (6a) and (6b) the exchange rate between the Naira and the CFA Franc X_t.

Three sets of F-tests are conducted on the above equations for each possible pair of districts. Unlike Ravaillon (1986), we do not assume the existence of a central market given that there is no central livestock market covering all of Niger. Even at the regional level, it is seldom clear which market is more central, as was illustrated in Figure 3. Equations (6a) and (6b) can nevertheless be used to test for market integration without formally postulating the existence of a central market, provided that all locations are treated symmetrically and that each set of tests are performed on both equations simultaneously.

First we test the null hypothesis that markets in regions *i* and *j* are segmented, that is, entirely unrelated:

$$H_0 : \alpha_1 = \beta_1 = \alpha_3 = \beta_3 = 0$$

The results, summarized in Table 3, show that prices in one district help determine prices in the other for about half the pairs of districts considered. This is a remarkable result given that many pairs of markets are quite distant from one another and physically linked only through intermediate markets.

Second we test the null hypothesis that both markets are jointly integrated in the short run, that is, that price movements in one district only depend on instantaneous price movements in the other, not on lagged price movements in either district:

$$H_0 : \alpha_1 = \beta_1 = 1 \text{ and } \alpha_2 = \alpha_3 = \beta_2 = \beta_3 = 0$$

On the basis of the results, we overwhelmingly reject the short term integration of livestock markets in Niger: the null hypothesis is rejected in 90 to 100 percent of the cases, depending on the animal category. The third set tests the null hypothesis that both markets are jointly integrated in the medium term, that is, that price movements tend to converge after a couple months:

$$H_0 : \alpha_1 + \alpha_2 + \alpha_3 = \beta_1 + \beta_2 + \beta_3 = 1$$

Results overwhelmingly reject medium term integration.[10]

To summarize the evidence presented so far, livestock markets in Niger appear only loosely integrated. Although prices in different districts rarely move in total isolation from price movements elsewhere, the forces that prevent prices from drifting arbitrarily

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[10] Test results from medium-term and short-term integration may be biased because $P_{i,t-1}$ and $P_{j,t-1}$ are non-stationary and consequently the *F*-statistic has a non-standard distribution (see discussion above). We tried to test long term integration with more lagged prices, but were prevented from doing so by the irregular pattern of missing observations.

apart appear surprisingly weak. Co-movements in prices are not the only possible basis on which one can test market integration, however. If markets are efficient, price differentials should never exceed the cost of moving livestock between them. Differences in livestock prices across districts can thus serve as an additional indicator of market integration. To these we now turn.

Section 4. Spatial Arbitrage and Parity Bounds

If markets are efficient and spatially integrated, price differentials across districts should reflect trade patterns: prices should be lower in distant production areas and higher close to urban centers and export points, and they should fall in concentric circles as one moves away from consumption and export centers. To check whether this is the case for livestock in Niger, we compute price differentials across districts.

To do so, we do not rely on sample averages of district-level prices. Indeed, because livestock prices vary between years and across seasons, sample averages depend on patterns of missing observations which vary considerably across districts. Using sample averages to infer price differentials would produce biased estimates. To derive an accurate measure of regional price differences on the basis of the existing data, we must control for other factors affecting prices and isolate the independent effect of location. We estimate the following regression:[11]

$$P_{i,t} = \kappa + \sum_{s=0}^{3} \beta_{i,s} R_{i,t-s} + \lambda_i N_{i,t} + \sum_{j \in J_i} \sum_{s=0}^{3} \beta_{j,s}(R_{j,t-s} - R_{i,t-s}) + \sum_{j \in J_i} \lambda_j (N_{j,t} - N_{i,t}) + \\ + \sum_{o=2}^{21} \theta_o Y_t + \sum_{m=1}^{11} \gamma_m M_t + \sum_{k=2}^{38} \alpha_k D_k + \sum_{r=0}^{2} \eta_r T_{t+r} + e_t \quad (7)$$

[11] Although we have shown in section 3 that district level prices nearly always test non-stationary, the combined data is stationary: results of an augmented Dickey-Fuller test on all the districts combined yield values well below the critical value for all animal categories (see Fafchamps and Gavian (1995)).

where $P_{i,t}$ and $R_{i,t}$ are deflated livestock price and deviation from average half-yearly rainfall, respectively. J_i is a set of three districts immediately neighboring district *i*. Variable $N_{i,t}$ stands for the two-year cumulative deviation of rainfall from its sample mean in district *i* at month *t*, truncated above zero, i.e. $N_{i,t} = Min\ (0\ ,\ \sum_{s=0}^{3} R_{i,t-s})$. Its role is to control for the effect of droughts. Variables Y_t, M_t and D_i are dummy variables for year, month and district, respectively. T_{t+r} is a dummy variable equal to 1 if Tabaski takes place during month $t+r$. These dummies control for cyclical and seasonal forces that affect livestock prices. Residuals e_t are assumed to follow an AR(1) process. Equation (7) is estimated via maximum likelihood.

Estimated district dummy coefficients are highly correlated within the cattle and small ruminants categories. Results are therefore best summarized by dividing district coefficients by the corresponding average animal price and averaging over all cattle and small ruminants. Price differentials between districts, presented in Figures 4 and 5 for cattle and small ruminants, respectively, do not fully conform to what one would expect from integrated markets. The prices of both cattle and small ruminants are consistently higher in local consumption centers like Niamey and Arlit, and at export points like Dosso, Birni Nkonni, Madarounfa and Matameye. They are also consistently lower in a production area like Tanout. But prices do not fall smoothly as one moves away from high price to low price areas. Several low price districts -- e.g., Magaria, Aguie, Tera and Loga -- are right next to a high price district. One of them, Aguie, is a low price area for both cattle and small ruminants even though it is on the Nigerian border and is sandwiched between two high price areas, Madarounfa and Matameye. Magaria is a low price area for cattle, and yet the descriptive literature (e.g., Makinen and Ariza-Nino

(1982)) and the analysis conducted in the previous section both indicate that it is a key regional market, closely integrated with those of neighboring districts. These results are, at *prima facie,* difficult to reconcile with the idea of market efficiency.

To investigate the matter further, we examine how price differentials between districts evolve over time. Figure 6 presents the differential in the price of steers between two important livestock markets of central Niger, Magaria and Tessaoua.[12] The Figure indicates that an important flow reversal may have taken place: prices in Tessaoua were lower than those in Magaria until the mid-1970s', but remained higher thereafter. This pattern suggest that livestock was initially flowing from Tessaoua to Magaria, but that for unknown reasons,[13] it began flowing from Magaria to Tessaoua around 1975. To verify whether flow reversals constitute a cause for concern, we compute, for each pair of districts, the percentage of observations for which the price differential is positive. We then plot the frequency distribution over all district pairs (Figure 7). If livestock always flow in the same direction, prices in downstream districts should consistently be higher than in upstream locations. One should therefore observe a bimodal distribution, upstream districts having a low percentage of positive price differentials with other districts, and downstream districts having a high percentage. As shown in Figure 7 for cattle, the distribution is in fact unimodal and symmetrical: for most district pairs, price differentials are half the time positive and half the time negative. The absence of flow reversal is thus extremely unlikely.[14]

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[12] To improve readability, both price differentials are divided by the average steer price.

[13] Possibly to avoid detection from customs agents.

[14] Large variations in animal quality may also contribute to the observed pattern. We come back to this issue later.

To investigate the effect of flow reversals on market integration, we examine whether livestock price variability was affected by the sudden collapse in animal prices that followed the 1984 drought and the decrease in uranium and oil export revenues. The reversion of livestock flows and the disorganization of markets that followed the shock are indeed expected to increase the unexplained spatial variance of prices. A formal test of this conjecture is constructed in the spirit of a Breuch-Pagan heteroskedasticy test. First a series of regressions are run on the years 1975 to 1988 covering two clearly distinct periods: a stable period of high prices from 1975 to 1983, and a period of price instability from 1984 to 1988. The regressions have the form:

$$P_{i,t} = \sum_{i=2}^{38} \alpha_i D_i + \sum_{s=0}^{23} \beta_s R_{i,t-s} + \sum_{m=2}^{12} \gamma_m M_m + \nu V_t + \kappa X_t + \sum_{r=0}^{2} \eta_r T_{t+r} + \sum_{o=2}^{21} \theta_o Y_o + e_t \quad (8)$$

and are corrected for autocorrelation. The residuals $\hat{e}_t$ from this regression are saved and two other regressions are run. In the first, squared residuals $\hat{e}_t^2$ are regressed on a constant term and a dummy that takes the value 0 from 1975 to 1983 and 1 afterwards. In the second, we keep the same independent variables but replace the dependent variable with $\frac{|\hat{e}_t|}{\hat{P}_t}$, i.e., with the absolute value of each residual divided by the predicted value of prices. The first regression tests whether the variance of the residuals -- and therefore the unexplained variance in prices -- was higher or lower after 1984. The second regression does the same for the coefficient of variation of the residuals -- that is, the relative variability of prices that remains unexplained by the model.

Results show that the *absolute* amount of noise in livestock prices decreased after the 1984 shock because prices were lower: in all regressions the coefficient of the dummy variable is negative; for 13 animal categories out of 15 it is significant at the 10 percent level. The *relative* amount of noise, however, significantly increased for large animals and castrated rams, that is, for the animals most actively traded (Table 6). This result is consistent with the idea that, as market operators struggle to absorb the adjustment of supply and demand and the successive reversal in trade flows, transaction costs go up and relative price volatility increases.

The presence of flow reversals may explain why district dummy coefficients are hard to interpret and why standard tests mostly reject market integration. Indeed, as has often been noted in the literature (e.g., Timmer (1986), Baulch (1994)), patterns of price co-movements are a good indicator of market efficiency only if goods always flow in the same direction. In the presence of transportation and other transaction costs, flow reversals cause prices to switch between import and export parity prices (e.g., Timmer (1986)). If flow reversals are sufficiently frequent, standard test of market integration may erroneously conclude that markets are unrelated (Baulch (1994)).

We now verify whether livestock markets in Niger are efficient using an alternative approach that allows for flow reversals. This approach can be summarized as follows. Suppose that the transportation and transaction cost of moving an animal from district i to district j is K_{ij}. If $P_{i,t}$ falls below $P_{j,t} - K_{ij}$, it is advantageous to purchase livestock locally at price $P_{i,t}$, transport it to district j at cost k_{ij}, and sell it at price $P_{j,t}$. If, on the other hand, $P_{i,t}$ exceeds its import parity bound $P_{j,t} + K_{ij}$, it is advantageous to purchase livestock in district j and transport it to district i. In the presence of perfect arbitrage, the price in district i should remain between (or exactly at) the export and import parity bounds. Market efficiency implies that the price gap between districts i and j should remain smaller or equal to K_{ij}, i.e., that:

$$|P_{i,t} - P_{j,t}| \leq K_{ij} \quad (9)$$

If K_{ij} is known, one can empirically check market integration between two districts i and j by verifying how often equation (9) is violated. Information that would allow a precise estimation of K_{ij} is lacking, however. We remedy this situation by constructing a somewhat arbitrary but conservative estimate of K_{ij}. The reason for choosing a high estimate of K_{ij} is that, if we nevertheless observe that prices violate their parity bounds, this can be interpreted as fairly conclusive evidence of market inefficiency. The descriptive literature on Niger often contrasts the behavior of livestock producers who typically sell their animals on local markets, and that of professional traders who are primarily interested in assembling large herds for long distance treks (e.g., Bellot (1982), Makinen and Ariza-Nino (1982), Staatz (1979) for Ivory Coast). As far as we can judge, there are no professional intermediaries in charge of arbitraging livestock prices differentials between neighboring districts. We therefore derive a conservative value for K_{ij} by considering whether an individual producer who has an animal for sale would find it profitable to sell it in another district.

To estimate of how much it would cost an individual producer to move an animal across district boundaries, we assume that each day's work is worth around 5 US dollars,[15] that animals can walk 20 Km. per day (e.g., Eddy (1979), Staatz (1979)), that producers must walk back to their district of origin, and that as many as 10 days may be lost just for deferring a sale.[16] We add an extra 300 CFA Francs to cover the cost of capital.[17] We thus have: $K_{ij} = (11 + 2\ d_{ij} / 20)$ 300 Francs, where d_{ij} is the average distance

[15] That is, 300 CFA Francs in 1964, the reference date used in this paper.

[16] Three days to prepare for travel, and seven days on average to wait for a good market day. Bellot (1982) indeed insists that a seller who can afford to wait catches a much better price. There would be little point in travelling to another district if one were not prepared to wait for a good market day.

[17] I.e., two percent monthly interest on the average cost of a steer, which is 15,314 CFA Francs of 1964.

between districts i and j in Km. Given the paucity of quantified data on arbitrage costs, these assumptions are somewhat arbitrary but they are very conservative. If, for instance, the producer decided to sell not one but two heads of livestock, the arbitrage cost per animal K_{ij} would fall by half since essentially the same time is required to move one or two heads of cattle (e.g., Eddy (1979)).

Figure 8 shows how often the prices of various types of cattle violate equation (9) as a function of the distance between districts. It immediately apparent that, for distances inferior to 100 Km., cattle prices violate our generous parity bounds about 30 percent of the time. In other words it appears that, a third of the time, individual producers could have made substantial profits by selling their animals in a neighboring district. Although parity bounds are violated less often as the distance between districts and thus K_{ij} increase, in 15 to 20% of the time it still appears profitable to sell cattle as far as 250 Km away.

These results constitute additional evidence of the presence of market inefficiencies in livestock trade. They may, however, be biased by the existence of quality differentials between animals. Indeed, unlike grain, animals are not homogeneous commodities. Their price vary with age, weight, health, and animal condition. Cattle destined for export, for instance, are often fattened and sold as *boeuf gras* (e.g., Makinen and Ariza-Nino (1982), Bellot (1982), and Staatz (1979) for Ivory Coast). Similarly, rams are typically fattened for the Moslem celebration of Takaski. Traders interviewed by Bellot (1982) cited differences in quality 45 percent of the time to explain animal price variation (p. 106).

The distinction between six categories of cattle and three categories of goat and sheep in the Niger data controls partially but not perfectly for these differences. We were unable to find quantitative evidence on quality differentials in Niger, but we computed that, in Botswana, the coefficient of variation in animal prices due to quality is equal to 0.18.[18] Since livestock in Botswana is produced in semi-arid conditions similar to that encountered in Niger, this number may be representative of Nigerien conditions as well. Applied to Nigerien steer prices, it translates into a standard deviation of 2,756 CFA Francs of 1964. For the sake of comparison, the standard error of the residuals in equation (10) can be seen as an alternative approximation of price variation due (at least partly) to quality. It is only slightly higher -- 3,335 CFA Francs of 1964. It is therefore possible that situations in which parity bounds are violated could be explained by differences in quality.

To explore this possibility, we use a model developed by Sexton, Kling and Carman (1991) and extended by Baulch (1994). Let the arbitrage cost between two districts *i* and *j* be made of two components, a constant K_{ij} and a random component $\theta_{ij,t}$ with variance σ^2_θ. To allow for quality variation, let $\varepsilon_{i,t}$ represent the variation in livestock price due to quality differences and other characteristics of the sale not controled for in the data. Denote the variance of $\varepsilon_{i,t}$ as σ^2_ε. If markets are efficient, the quality-corrected price $\bar{P}_{i,t} \equiv P_{i,t} + \varepsilon_{i,t}$ must satisfy $|\bar{P}_{i,t} - \bar{P}_{j,t}| \leq K_{ij} + \theta_{ij,t}$. This yields the following condition for market integration:

$$|P_{i,t} - P_{j,t}| \leq K_{ij} + \theta_{ij,t} - \varepsilon_{i,t} - \varepsilon_{j,t} \equiv K_{ij} + v_{ij,t} \qquad (10)$$

If shocks are independent, the variance of $v_{ij,t}$, σ^2_v, is equal to $\sigma^2_\theta + 2\,\sigma^2_\varepsilon$.

Prices can be in one of three regimes: they can be at the parity bound, in which case equation (10) holds with equality; they can be inside the parity bound, in which case:

[18] Our computation is based on grading system data from slaughterhouses reported by Ansell (1971) (p.47).

$$|P_{i,t} - P_{j,t}| = K_{ij} + v_{ij,t} - u^1_{ij,t} \tag{11}$$

or they can be outside the parity bounds, in which case:

$$|P_{i,t} - P_{j,t}| = K_{ij} + v_{ij,t} + u^2_{ij,t} \tag{12}$$

We want to know how often prices in districts i and j are in either of these three regimes. To do so, we construct a switching regression model based on equations (10), (11) and (12). Let $Y_{ij,t} \equiv |P_{i,t} - P_{j,t}|$. Following Sexton, Kling and Carman (1991) and Baulch (1994), assume that $v_{ij,t}$ is normally distributed, and that $u^1_{ij,t}$ and $u^2_{ij,t}$ both follow a normal distribution truncated below zero: indeed, prices in equations (11) and (12) presumably remain clustered around the parity bounds. Given these assumptions, we can define the likelihood of being in either of the three regimes as:

$$L_{ij}(\lambda_1, \lambda_2, \sigma_v, \sigma_1, \sigma_2, K_{ij} \,|\, P_{i,t}, P_{j,t}) = \prod_{t=1}^{T} [\lambda_1 f^1_t + \lambda_2 f^2_t + (1 - \lambda_1 - \lambda_2) f^3_t] \tag{13}$$

where λ_1 and λ_2 are the probabilities that prices are at the parity bounds or within the parity bounds, respectively. Expressions f^1_t, f^2_t, and f^3_t are defined as follows:

$$f^1_t \equiv \frac{1}{\sigma_v} \phi \left(\frac{Y_{ij,t}}{\sigma_v} \right) \tag{14}$$

$$f^2_t \equiv \left[\frac{2}{(\sigma_v^2 + \sigma_1^2)^{1/2}} \right] \phi \left[\frac{Y_{ij,t}}{(\sigma_v^2 + \sigma_1^2)^{1/2}} \right] \left[1 - \Phi \left[\frac{Y_{ij,t}\, \sigma_v/\sigma_1}{(\sigma_v^2 + \sigma_1^2)^{1/2}} \right] \right] \tag{15}$$

$$f^3_t \equiv \left[\frac{2}{(\sigma_v^2 + \sigma_2^2)^{1/2}} \right] \phi \left[\frac{Y_{ij,t}}{(\sigma_v^2 + \sigma_2^2)^{1/2}} \right] \left[1 - \Phi \left[\frac{-Y_{ij,t}\, \sigma_v/\sigma_2}{(\sigma_v^2 + \sigma_2^2)^{1/2}} \right] \right] \tag{16}$$

where σ_1 and σ_2 are the standard deviation of $u^1_{ij,t}$ and $u^2_{ij,t}$, respectively. Functions $\phi(.)$ and $\Phi(.)$ stand for the standard normal density and cumulative density functions. Being probabilities, λ_1 and λ_2 are constrained to remain between 0 and 1. Techniques for maximizing equation (13) are discussed in Baulch (1994).

Equation (13) in principle permits the joint estimation of K_{ij} and the three variances σ_v, σ_1, and σ_2 (e.g., Sexton, Kling and Carman (1991)). As in many switching regression models, however, parameter estimates are identified only thanks to distributional assumptions. Results should therefore be treated with caution. In an effort to improve the robustness of our estimates, we also maximize the log-likelihood (13) using our own conservative estimates for K_{ij} and σ_v. In the latter case, we assume that variation in arbitrage cost θ_t is small, that σ_v is dominated by quality variation $2^{\frac{1}{2}}\sigma_\varepsilon$, and that σ_ε = 2,756 CFA Francs. Given that nearby districts are those for which violations of parity bounds seem to be the most serious, we focus on pairs of districts that are close to each other and select those for which the number of observations is large.[19]

Parameter estimates are presented in Table 7 for steer prices. Unconstrained estimates of λ_3, the probability that prices are outside the parity bounds, are large and significant in virtually all regressions, thus providing further evidence of market inefficiency. If we constrain K_{ij} to be equal to our conservative estimate of arbitrage costs for cattle, estimates of λ_3 fall somewhat but remain large and significant in adjacent districts. Steer prices are mostly inside their parity bounds: the presence of large arbitrage costs decouples markets from each other, possibly explaining why prices often fail to co-move, even on short distances. Estimates of σ_v^2, the standard deviation of combined shocks in animal quality and arbitrage costs, tend to increase with distance but remain mostly below our own conservative estimate of the standard deviation of quality alone. If we restrict σ_v to be equal to $2^{\frac{1}{2}}$ x 2,756 CFA Francs, estimates of λ_3 fall further, but even so, they remain moderately significant in four of the six cases examined.

[19] Maximizing the likelihood function (13) is much more time consuming than estimating co-integration or Granger causality models. Running the parity bounds model for all pairs of districts and all animal categories is beyond the scope of this paper.

Taken together, these results indicate that large arbitrage costs and variations in animal quality can in principle explain most of the observed pattern of price differentials. What remains a mystery, however, is why market operators do not take advantage of returns to scale in livestock transportation to capture gains from spatial arbitrage. This issue deserves more research.

Conclusions

Using a large data set from Niger, we measured the extent of livestock market integration. A wide variety of market efficiency measures were used: we tested for co-integration and Granger causality, estimated a version of Ravallion's model, computed average price differentials, and estimated a parity bounds model. The evidence all points in the same direction: Nigerien livestock markets are related but not closely integrated.

These results should perhaps not come as a surprise, given that more than 1600 kilometers separate the eastern side of Niger from its western side, that most livestock movements take place by foot, and that the trekking of livestock requires adequate water and pasture along the way. The lack of market integration can thus be blamed in part on the long distances involved and on the rudimentary way in which animals are transported from one market to another. Price fluctuations are further compounded by heterogeneity in animal quality.

Long distance trade, as opposed to local arbitrage, appears to be what guarantees a modicum of market efficiency. Major long distance markets play a key role in spreading price movements spatially. Shocks that affect well established livestock assembly points tend to ripple through the system, while markets located downstream operate as a sink for shocks originating upstream. The critical role of long distance trade is confirmed *a* *contrario* by the finding that, when it is disorganized by aggregate supply and demand shocks, price volatility increases between districts. Prices in districts with presumably thin livestock markets remain dominated by idiosyncratic shocks, however, and appear largely isolated from price movements elsewhere.

Although these results are not altogether unexpected, they suggest that there is plenty of room for improvement in the functioning of livestock markets in Niger. So doing would undeniably favor a more efficient use of pasture resource in a part of Africa characterized by endemic droughts and evidence of localized overgrazing. It would also promote a better sharing of risk across space, not only for pastoralists but also for all the farmers who use livestock as a form of precautionary saving.

How market efficiency can be improved cannot assessed on the basis of price series alone. The descriptive literature insists that efforts by the Nigerien government to tax and regulate livestock imports and exports have led traders and producers to operate in a semi-clandestinity (e.g., Bellot (1982), SEDES (1987), Eddy (1979), Staatz (1979), Makinen and Ariza-Nino (1982)). Although all authors emphasize that enforcement has been weak, efforts to avoid taxation have probably been detrimental to trade, particularly local trade. Indeed, given Niger's geographical configuration (the large majority of the population lives less than a 100 miles from an international boundary), any local purchase of livestock is potentially an export or an import, and is therefore potentially taxable. It is possible that livestock traders neglect domestic arbitrage in order to avoid attracting custom officers' attention on the more lucrative part of their business, exports and imports. Additional research is needed on these issues, but we suspect that a more positive attitude by government authorities coupled with investments in trekking routes, rail, and road transport could significantly improve the efficiency of livestock markets.

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